

Historic, Archive Document

Do not assume content reflects current scientific knowledge, policies, or practices.

60.11
5083

United States
Department of
Agriculture

Agricultural
Research
Service

October 1986

Proceedings of the 42nd Southern Pasture and Forage Crop Improvement Conference

Held at Athens, Georgia
April 15-16, 1986

United States
Department of
Agriculture

Agricultural
Research
Service

Proceedings of the 42nd Southern Pasture and Forage Crop Improvement Conference

**Held at Athens, Georgia
April 15-16, 1986**

Sponsored by the
Agricultural Experiment Stations
of Alabama, Arkansas, Florida, Georgia,
Kentucky, Louisiana, Mississippi,
North Carolina, Oklahoma, Puerto Rico,
South Carolina, Tennessee, Texas, and Virginia
and the
Agricultural Research Service
U.S. Department of Agriculture

The papers in this report are reproduced essentially as they were supplied by the authors. The opinions expressed are their own and do not necessarily reflect the views of the U.S. Department of Agriculture.

This camera copy was prepared and edited in the office of John D. Miller, Forage and Turf Unit, Coastal Plain Station, Tifton, GA 31793.

Copies of this report can be purchased from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161. ARS has no additional copies for distribution.

As the papers were prepared in reproducible form by the individual authors to expedite the publishing of the proceedings, there is some variation in type and format; however, such variations should not distract the attention of the reader. Queries regarding them should be referred to authors of the specific papers.

PREFACE

These proceedings include most of the papers and reports presented at the 42nd meeting of the Southern Pasture and Forage Crop Improvement Conference (SPFCIC) held April 15-16, 1986, at Athens, Georgia with the University of Georgia as host. Many of the sessions and tours were joint with the American Forage and Grassland Council (AFGC) whose meetings continued through the morning of April 18. Information Exchange Groups (formerly Work Groups) met during the morning of April 15 with many reports included later in these Proceedings. A tour of the research plots of the University of Georgia and the USDA-ARS Southern Piedmont Research Center, Watkinsville, GA, was made that afternoon. An extensive display of plot machinery was assembled at Watkinsville. A barbecue dinner at Finchum's Phoenix Forestry Center on the University of Georgia campus completed the day.

During the morning of April 16, five invited speakers addressed the combined membership of AFGC-SPFCIC. These papers are included in the first section of these Proceedings. The joint afternoon session ended with a business meeting of SPFCIC. The minutes and related matters as well as a list of Conference Registrants are included at the end of this report. Participants were introduced state by state.

These Proceedings are dedicated to Dr. Glenn W. Burton, Research Geneticist, USDA-ARS. A brief sketch of Dr. Burton's career prepared by Dr. Homer D. Wells follows.

DEDICATION

The idea of the Southern Pasture and Forage Crop Improvement Conference (SPFCIC) was promulgated during 1939 and a preliminary organizational meeting was held during the Association of Southern Agricultural Workers

Annual Meeting February 8, 1940 at Birmingham, AL. The first SPFCIC meeting was held at Tifton, GA, July 23-24, 1940. More than 40 members were in attendance at this first meeting. Many of the charter members are deceased and all of the others, except Glenn W. Burton, have retired from their careers of service. Prior to our meeting in April, Glenn completed (January 30, 1986) his 50th year of service as a Research Geneticist with the USDA-ARS. Thus it was suggested and approved by the Executive Committee of SPFCIC that the Proceedings of the 42nd SPFCIC be dedicated to Dr. Glenn W. Burton for his 50 years of service to ARS.

While Glenn is recognized for his outstanding service to the SPFCIC beginning by co-hosting, along with J. L. Stephens and B. L. Southwell, the first SPFCIC and his many other contributions to the Conference throughout the years, we wish to call to your attention his major contributions to forage and turf on a worldwide basis. Glenn's forage and turf types of bermudagrass are grown in the tropical, subtropical and milder temperate zones throughout the world. His pearl millet breeding program has not only proven of significance in forage production, but has had a major impact in areas of India and Africa, where this crop serves as a major source of grain for human nutrition. We are accustomed to seeing Glenn always in high gear and too busy to play; thus, we fail to realize his dedication to sports and recreation. Glenn's series of Tift hybrid turf bermudagrasses developed as a sideline to his forage breeding program has had a significant impact on sportsmen of all ages and of varying degrees of expertise. A toddler rolling on a lawn in Atlanta, GA, and a doddering elderly man banging a croquet ball in Palm Beach, Florida, are both likely to be playing on one of the bermudagrasses developed by Glenn. The beginning or novice ball player in a park or school playground throughout the South is likely to be playing on a bermudagrass turf planted from one of Dr. Burton's hybrids. Also when we lay back in our easy chair to see the world's best football players or golfers on television, the turf that they perform on is often a bermudagrass developed by Glenn. Dr. Burton, for these and the many other contributions that you have made for the betterment of our lives, we are proud to dedicate these Proceedings to you.

Homer D. Wells

CONTENTS

	Page
Invited Speakers	1
Chairman - Carl Hoveland	
Forages for the Future ~ Glenn W. Burton	1
The Future of Forage Quality Evaluation - Gordon C. Marten and Neal P. Martin	4
The Dairy Industry and Its Future - Dave Mertens	13
Grass - The Next Cinderella Crop - H. Allan Nation	17
The Beef Industry and Its Future - David G. Topel	20
Breeders Research Information Exchange Group	24
Chairman - Gary A. Pederson	
Forage Legume Breeding in Florida - David Baltensperger, G. M. Prine, and K. H. Quesenberry	24
Germplasm Improvement in the Mississippi Clover Breeding Program - W. E. Knight, M. M. Ellsbury, M. R. McLaughlin, G. A. Pederson, R. G. Pratt, and G. L. Windham	26
Breeding of Serecia Lespedeza (<u>Lespedeza</u> <u>cuneata</u> (Dumont) G. Don.) in Alabama. A Historical Outlook - Jorge A. Mosjidis.	30
Trefoils for the Southeast - J. F. Pederson and C. S. Hoveland	34
A New Look at Rose Clover - G. R. Smith	37
Extension Research Information Exchange Group	41
Chairman - Wade Faw	
The Benefits of Fescue Pasture Renewal - James E. Standaert	41
Forage Utilization Research Information Exchange Group	47
Chairman - David G. St. Louis	
Progress of S-167 Regional Project - C. P. Bagley	47
Yield and Quality Differences Among Cultivars of Endophyte-free Tall Fescue - Joe Bouton	48
Exploring the Plant-Animal Interface - Diet Selection, Canopy Structure and Intake Measurement Problems and Solutions - J. R. Forwood	50
Canopy Structure Effects on Ingestive Behavior - J. E. Moore and L. E. Sollenberger	53
Summary of Regional Project S-156, Simulation of Forage and Beef Production in the South- ern Region - L. M. Tharel, M. A. Brown and E. M. Smith	58
Appropriate Markers and Methodology for Grazing Research - K. R. Pond, J. C. Burns, D. S. Fisher, and R. A. Quiroz	62
Business Meeting and related matters	67
Conference Registrants	68
Mention of trade names or companies does not imply recommendation or endorsement by the U. S. Department of Agriculture over others not mentioned.	

FORAGES FOR THE FUTURE

Glenn W. Burton¹

INTRODUCTION

Forages have contributed greatly to man's well being for thousands of years. While yet a hunter, he supplied most of his food and clothing from forage-consuming animals. When domesticated, these animals; cattle, sheep, horses, goats, etc.; became symbols of wealth and provided food, clothes and power to transport burdens and till the soil.

The first forage to be intentionally planted by man was probably alfalfa. As early as 490 BC, when the Medes and Persians invaded Greece, they introduced alfalfa to feed their chariot horses, camels, and domestic animals. Many of the cool season grasses and clovers were brought to the United States by the early colonists. Most of the cultivated forages in the U.S. today were introduced from other countries and have been planted in the past century.

In 1979, Kunz and Purcell (1982) concluded that more than one-third of the value created in U.S. agriculture, was attributed directly or indirectly to forage. They did not attempt to evaluate the important role that forages play in soil conservation, the reduction of erosion and the improvement of soil fertility.

I believe the need for forages will grow. The population explosion will see to that as people compete with livestock for grain. It took till 1830 to put the first billion people on earth. It took 100 years to add the second billion, 30 years to add the third, 15 years to add the fourth, and just 10 years to add the fifth. If population continues to increase at its present rate, the world must feed 8 billion people by the year 2010.

Only 5% of the earth's surface is arable, suitable for growing crops. The best 3% is presently feeding the world. The other 2% is producing wood and other products needed by man. Much of the arable land needs the protection of forages.

Forage fed beef will contain less of the excess fat that characterizes most grain fed beef. It will help to satisfy the growing demand for low-fat diets.

I believe the future will see the planting and use of more forage but the forages must be better than those in general use today. Although adapted sod forming perennial forages can protect erodible soil better than other plants, they must do more. They must produce feed for livestock at a reasonable profit to the landowner. The choice of forage species that can do this will require the experience and judgement of

plant and animal scientists working together. Germplasm collections thought to have forage potential must be evaluated. Certainly, the forages chosen must be adapted to the environment, particularly when defoliated by or for livestock. New species may appear but most species with forage potential have been planted in the South many times. Their success or failure has been influenced by the fertilization and management that they received. Given better management, species discarded may reappear. Correcting their genetic weaknesses must be the job of the forage breeder with the help of scientists from other disciplines as needed. A description of some of the major tasks and suggested procedures follows:

Future forages must be dependable. A forage that fails because of mismanagement or adverse weather will force its user to sell his animals at a loss or pay too much for replacement feeds. Perennials that survive will be more dependable than annuals because they are less dependent on weather and management to produce seed and become established each year. Crabgrass, Digitaria sanguinalis, is a very good warm season pasture grass. A south Georgia farmer who successfully used it for several years, planted Coastal bermudagrass after he failed to get grazable stands of crabgrass.

Persistence is probably the best test of dependability. Many grass and legume species have been planted in the South. Only three grasses, tall fescue, Festuca arundinacea; Pensacola bahiagrass, Paspalum notatum; and bermudagrass, Cynodon spp., pass this test. These grasses are the base for most improved pastures and may continue to be for some time. As long as they are the base, they warrant the greatest improvement effort.

Lack of dependability is the greatest weakness of the many legumes that have been planted in perennial pastures across the years. Crimson clover, Trifolium incarnatum, that once occupied a million acres in Georgia, has largely disappeared. Adverse weather and mismanagement that failed to produce a seed crop every spring and establish a stand every fall were contributing factors. But lack of dependability and failure to produce the dependable results obtained from a dependable grass plus nitrogen caused farmers to lose interest. As legume breeders search for better species and strive to improve the best they have, dependability must be one of their major objectives.

Increasing the tolerance of grasses and legumes to stresses such as drought and cold will improve their dependability. Such progress in both areas has been demonstrated in our bermudagrass breeding. Coastal bermuda, about twice as productive as common bermudagrass in a good year, produced six times more forage in a very dry year. Tifton 44 is dependable farther north than Coastal, thanks to its hardiness genes from a common bermuda found in Berlin, Germany. Germplasm collections and better screens for drought and cold stress will be needed to make future forages more cold and drought tolerant.

¹Research geneticist, USDA-ARS, and Univ. of Ga. Coastal Plain Exp. Station, Tifton, GA 31793.

Future forages must be more resistant to diseases, insects, and weeds. Improving their resistance will also make them more dependable.

Because animals eat about the same amount of forage each day, future forages to be grazed will have a more uniform growth rate over a longer period of time than the best we have today. For processing into hay or silage, rapid seasonal growth that gives a high yield of high dry matter forage will be preferred.

Costs of establishment and production must be kept low for forages to compete with other land uses. One of the best ways to do this is to develop cultivars of adapted forages that can produce more forage with the same inputs. Such cultivars must be more efficient in recovering or utilizing one or more of the growth factors (water, CO_2 , light, temperature, and plant nutrients). A number of plant breeding methods are available to do this.

Synthetic Cultivars. The method most frequently used in improving forages is the development of synthetics. Superior plants screened from germplasm collections are usually grouped together with or without testing for compatibility. Usually they flower at about the same time and have similar important traits such as disease resistance. The parent clones are frequently retained to continually supply breeders seed and prevent drift. By the time the synthetic is increased enough to reach the consumer (syn 4 or later), most of the heterosis that might have been in syn 1 has been lost.

Mass Selection. Mass selection, the oldest plant breeding method, can be effective for improving characteristics with a high heritability. Florida 77 alfalfa (*Medicago sativa*) the product of recurrent mass selection, is proof of its power (Horner and Ruelke, 1980). A good screen, an effective system for intermating selected plants and time are the ingredients required for success. Earl Horner, University of Florida agronomist, began a program to improve the persistence of alfalfa at Gainesville, Fla. in 1950. A consistant adverse environment that eliminated most plants in 2 to 3 years supplied the screen. Bees intermated the surviving plants, seed from which was used to plant the next cycle. Persistence had been significantly improved by cycle 6, released as Florida 66 in 1966 but the spotted aphid in the west prevented commercial seed production. An effective screen for spotted aphid resistance plus effective intermating by bees in 3 cycles increased aphid resistance from 0.005% to the 71.5% in an improved cultivar named Florida 77.

Recurrent Restricted Phenotypic Selection. A better method of increasing the yield and efficiency of a forage is recurrent restricted phenotypic selection (RRPS) that is four times more efficient than mass selection (Burton, 1974). In replicated seeded plots clipped five times per year, cycle 9 of RRPS has yielded 47% more dry matter than the Pensacola bahia check (Burton, 1985).

When we started to use mass selection to increase the forage yields of Pensacola bahiagrass in 1960, we did not expect much progress. The correlation between yields of spaced plants and their clonally established plots was only 0.4. We expected to need 2 to 3 years per cycle. We decided, however, to grow 1000 spaced plants, select the top 5 plants in each 25 plant block and intermate those 200 selections for the next cycle. During the past 25 years, we have modified procedures to improve the precision of our screen for yield and our intermating system. Today these eight modifications of mass selection called 'restrictions' enable us to complete one cycle of RRPS per year and increase the mean yield of the space planted population over 16% per cycle through cycle 9 (Burton, 1974, 1985). With slight modifications, I believe RRPS can be a very effective method for increasing the yield of many cross-pollinated forages such as tall fescue, *Festuca arundinaceae*.

F_1 Hybrids. Good F_1 hybrids can increase forage yields 20 to 100%. The challenge is developing methods to put the F_1 hybrid on the farm. The vegetatively propagated bermudagrass F_1 hybrids such as Coastal, Tifton 44, and Tifton 78 have doubled dry matter yields when compared with the common type. Breeding such vegetatively propagated hybrids requires less work and time than breeding those propagated by seed. If they, like Tifton 78 bermudagrass, can be established by disking into moist soil freshly mowed tops, the cost and time required for establishment can be less than for seed propagated forages.

Gahi 1 pearl millet, a first generation chance hybrid, gave the cattlemen the benefits of hybrid vigor long before other methods of producing commercial F_1 hybrid seed (Burton and Powell, 1968) were available. Seed for Gahi 1 were produced by harvesting all seed from a field planted to a mixture of equal quantities of pure live seeds of four inbreds that produced high yielding hybrids in all combinations. This seed contained 75% of the six possible F_1 hybrids which planted in the field crowded out the other 25% of selfs and sibs and yielded as well as the doublecross of the 4 inbred lines - 50% more than the cattail check. This method has also been successfully used to increase forage yields of sudangrass, *Sorghum vulgare sudanense*.

Cytoplasmic male sterility (cms) (in those species where it has been found) offers one of the best mechanisms for producing F_1 hybrid seed. Hybrid forage sorghums and pearl millets such as Gahi 3 and Tifleaf 1 are seed propagated cms F_1 hybrids. I believe the future will see cms F_1 hybrids of other forages on the farm.

The future will most certainly seed a greater use of apomictic hybrids. These seed propagated hybrids breeding true and maintaining their desirable traits through succeeding generations will be a boon to the livestock industry. Higgins buffelgrass, *Cenchrus ciliaris*, is an apomictic F_1 hybrid bred at College Station, Texas (Taliaferro and Bashaw, 1966).

To increase yields of animal products and reduce production costs, yields must be increased without reducing quality. The quality of a forage is finally determined by the performance, usually average daily gains of livestock consuming it. Although digestibility, intake and utilization are characteristics that determine forage quality, digestibility is generally the most important. Digestibility usually correlates well with ADGs and can be measured with laboratory tests such as the in vitro dry matter digestibility procedure (IVDMD). The positive correlation that usually exists between digestibility and intake, permits some selection for intake with the IVDMD analysis or the near-infrared spectroscopy (NIRS) analytical tests. However, similar rapid inexpensive tests that might be used to screen forages for intake and utilization would be a boon to the forage breeder.

The quality of forages and the gains of livestock consuming them can be improved by removing inclusions that affect animal performance adversely. The asexual fungal endophyte, Acremonium coenophialum, is such an inclusion. The association of this endophyte with tall fescue toxicosis is one of the most significant forage discoveries of this century (Hoveland, et al, 1983). Research underway at several research stations in the South suggests that each 10% increase in tall fescue tillers infested with the endophyte reduces ADGs 0.1 lb. The endophyte is seed borne in tall fescue but usually dies in seed stored for 1 to 2 years after harvest. Research to date indicates that the endophyte does not spread from plant to plant.

There is evidence to indicate that plants infested with the endophyte are more resistant to the attack of certain insects. Thus removing the endophyte to improve the quality of tall fescue, may reduce its excellent adaptability.

Evaluation. Future cultivars should be thoroughly tested before releasing them to livestock farmers. Replicated small plot tests designed to measure seasonal distribution and total yield of forage plus IVDMD analyses of all forage harvested from each entry will help to separate the best from the better entries included in a test. The one or two with the best agronomic and small plot record should be included in feeding and grazing trials; preferably with the kind of animals that will finally use them. Animal scientists should help to conduct such tests and ideally should be a part of every forage team.

Distribution and Management. To make their maximum contribution to the livestock industry, the future forages must be grown wherever they are superior to other forages. With their distribution should go a management "package" that will enable them to reach their full potential. Crop Improvement Associations can often help with the increase and distribution of new cultivars. Exclusive release to one private company may be desirable, especially if seed

must be produced at great distances from the area of use.

Literature Cited

- Burton, G. W. 1974. Recurrent restricted phenotypic selection increases forage yields of Pensacola bahiagrass. *Crop Sci.* 14:831-835.
- Burton, G. W. 1985. Spaced-plant-population-progress test. *Crop Sci.* 25:63-65.
- Burton, G. W. and J. B. Powell. 1968. Pearl millet breeding and cytogenetics. In *Advances in Agronomy*, Vol. 20, pp. 49-89, Academic Press, New York.
- Horner, E. S. and O. C. Ruelke. 1980. Florida 77 alfalfa and recommended management practices for its production. *Univ. of Fla. Cir.* S-271.
- Hoveland, C. S., S. P. Schmid, C. C. King, Jr., J. W. Odom, E. M. Clark, J. A. McGuire, L. A. Smith, H. W. Grimes, and J. L. Holliman. 1983. Steer performance and association of Acremonium coenophialum fungal endophyte. *Agron. J.* 75:821-824.
- Kunz, Janice J. and Joseph C. Purcell. 1982. Value added (created) in United States Agriculture IR-6 Information Report No. 61. Interregional Cooperative Publication of the State Agriculture Experiment Stations, July.
- Taliaferro, C. M. and E. C. Bashaw. 1966. Inheritance and control of obligate apomixis in breeding buffelgrass, Pennisetum ciliare. *Crop Sci.* 6:473-476.

THE FUTURE OF FORAGE QUALITY EVALUATION

Gordon C. Marten¹ and Neal P. Martin²

INTRODUCTION

"Forage quality" and "feeding value" of forages are synonymous terms that must be broken down into sub-factors if we hope to develop and understand evaluation methods. Because animal performance is the ultimate expression of true feeding value, Marten (1985) placed it at the top of a list of factors that contribute to forage quality (see Figure 1). For purposes of discussion of the future of forage quality evaluation, we will concentrate on the two universal sub-factors that contribute to potential forage feeding value, namely potential nutritive value (especially energy nutrients and their digestibility) and potential intake by the ruminant animal. The degree of digestibility or of available energy from forages can be expressed by several terms that are all highly related. Among these are total digestible nutrients (TDN), digestible dry matter (DDM), digestible organic matter (DOM), and digestible energy (DE). We will select DDM because it is currently being used in hay quality standards and in many research and extension programs.

Fonnesbeck (1985) also featured voluntary intake and digestion when he recently listed the factors that influence alfalfa hay quality (see Figure 2). Therefore, we will consider mostly these two items as we look to the future of forage quality evaluation.

LABORATORY METHODS FOR EVALUATION OF FORAGE QUALITY

There are essentially four categories of laboratory methods for evaluation of quality of all types of forages. Among these are the following:

1. "See-Smell-Touch" (organoleptic);
2. "Protein-Fiber-Mineral" (chemical);
3. "Tube-Bag-Bunny" (microbial or biological);
4. "Grind-Sieve-Bombard" (physical).

These laboratory methods are discussed in detail in review articles by Barnes and Marten (1979) and Marten (1981). The

organoleptic methods are as old as history; they must still be relied upon to detect contamination of forages with foreign materials, toxic weeds, molds, etc. The Van Soest systems of fibrous feed analysis have become primary standards for chemical evaluation of forages throughout the world. Of special interest to us in this discussion are acid detergent fiber (ADF) as a predictor of digestibility (especially for alfalfa and temperate grasses) and neutral detergent fiber (NDF) as a predictor of intake potential of forages and of the proportion of grass in legume-grass mixtures. Concentrations of crude protein, specific minerals, and water in forages also are of major interest because the former two are required nutrients and the latter often indicates the conditions and type of forage curing and preservation. Moisture concentration must also be known in order for us to calculate nutrient concentration on a dry matter basis.

The laboratory method usually considered to be superior for the prediction of ruminant *in vivo* (in the animal) digestibility of forages is the *in vitro* (in the test tube) rumen fermentation technique. This method uses microbe-rich fluid taken from a hole in a ruminant's rumen to digest ground forages during incubation in the laboratory. This "artificial cow" approach is often used in research labs, but the procedure is costly and difficult to standardize in non-research situations. Also, the "nylon bag" approach, whereby small cloth bags containing ground forages are suspended in a cow's or sheep's rumen, is difficult to standardize and limited in the number of samples that can be efficiently analyzed. Recent evidence that very potent fungal enzymes (cellulases) that mimic the action of rumen microbes can be cultured in the laboratory may provide a good alternative for researchers who do not have access to live animals. However, a limited number of samples can be analyzed per unit time with these as well as with conventional chemical approaches.

The "bunny methods" (small animal bioassays) vary in their applicability to forage species. For example, rabbits can provide a good evaluation of relative quality of alfalfa harvested at a wide range of growth stages, but they do not usually successfully differentiate among grasses of varying quality. Again, small animal bioassays are quite costly and do not allow analysis of large numbers of samples on a routine basis.

The amount of electrical energy required to grind forage samples has at times been well associated with digestibility as well as intake potential of forages that have a wide range of quality. So too have the sieving properties of soaked, unchopped grasses and legumes. However, these methods are difficult to standardize, do not work for all forages,

¹Research Agronomist, U.S. Department of Agriculture, Agricultural Research Service, University of Minnesota, St. Paul, MN.

²Extension Agronomist, University of Minnesota, St. Paul, MN.

and do not apply to routine assessment of large numbers of samples.

Without question, the physical method that holds the greatest promise for routine measurement of nearly all facets of forage quality is near infrared reflectance spectroscopy (NIRS). This procedure, whereby radiation in the near infrared region of the electromagnetic spectrum is "bombarded" on finely ground samples of dried forages, and whereby the reflected light is captured and analyzed by a computer to indicate chemical composition and associated forage quality traits, has revolutionized forage quality evaluation.

NEAR INFRARED REFLECTANCE SPECTROSCOPY--- PHYSICAL MEANS TO ORGANOLEPTIC, CHEMICAL, AND MICROBIAL ENDS

The question is, can we "bombard" to do it all? The answer is, we're getting close! Because NIRS can provide the fast, precise, and outlier information sought by plant breeders, plant breeding is the uppermost area of research for which this new technology can be recommended without further development (Marten et al., 1985). NIRS has also already proved of great value for routine assessment of chemical composition, digestibility, and other quality traits (including sometimes intake) of forages needed by researchers concerned with forage crop management, forage physiology, and ruminant nutrition. In addition, extension specialists in several states have successfully used NIRS to determine crude protein, heat-damaged protein, several fiber traits, dry matter, digestibility, and minerals in hay, dried hay-crop silage, dried corn silage and dried high-moisture grain used in ruminant animal ration balancing (Adams, 1984; Martin et al., 1984; Rohweder, 1984). Mobile NIRS systems have further been used in extension programs and in private testing programs to aid buyers and sellers of hay in establishing equitable prices at auctions.

In the future, scientists hope to standardize NIRS for analysis of feed ingredients, concentrate mixtures or forage-concentrate mixtures, undried high-moisture feedstuffs, specific plant species composition of mixed forages, and micro components of forages (such as vitamins, toxins, and molds).

WHAT DOES ACCURATE AND TIMELY EVALUATION OF FORAGE QUALITY MEAN TO THE PRODUCER?

The Relative Feed Value Concept

In 1976, a task force of scientists cooperated with the American Forage and Grassland Council (AFGC) to develop a new hay grading and forage evaluation system based on chemical analysis

to predict both digestible dry matter (DDM) and dry matter intake (DMI). Acid detergent fiber (ADF) was used to predict DDM and neutral detergent fiber (NDF) was used to predict DMI. These two measures were then used to calculate digestible dry matter intake which, in turn, was converted to a scale that would allow a mid-to-full-bloom alfalfa hay that contained 40% headed grass to have a "relative feed value" (RFV) of about 100. Later, this grading system was slightly modified (Jorgensen et al., 1985) to provide the grades and descriptions given in Table 1. The proposed standards were complex and received only mixed support from industry; however, at least parts of these standards are used routinely today in extension programs in Wisconsin, Illinois, Minnesota, Oregon, Washington, Idaho, Utah, and other states.

In 1982, a group of scientists representing AFGC and hay industry representatives from throughout the nation met to establish a U.S. Alfalfa Hay Quality Committee. In 1983, common simplified standards were accepted, which have come to be known as the "National Alfalfa Hay Testing Association Standards".

The National Alfalfa Hay Testing Association Standards

The new standards that were devised by the U.S. Alfalfa Hay Quality Committee to be applied nationally include use of ADF (to calculate estimated digestible dry matter; EDDM), crude protein (CP), and dry matter (DM). The committee also allows nutritionists to calculate digestible energy from EDDM via local equations and suggests that visual and other organoleptic criteria (to vary by area) be included. The ultimate goal of the new association is to foster a nationally uniform marketing system that will permit hay to be priced on the basis of its feeding value. Both hay buyers and sellers will receive more accurate nutritional information in this equitable system. Livestock feeders will also be able to put the nutritional information to use as they balance rations.

The Subcommittee on Laboratory Certification of the original U.S. Alfalfa Hay Quality Committee issued a publication (1984) entitled "Hay Testing Laboratory Certification Manual" that outlines sampling, laboratory sample preparation and analyses, EDDM equations, NIRS applicability to predicting the chemical components needed for hay testing, and statistical information (data analyses and an outlier test) needed for laboratories to participate in a voluntary certification program jointly administered by the National Hay Association and the AFGC.

Other Evaluation Of Forage Quality For Producers

Various extension and industry programs

feature their own individual standards for estimating feeding value of forages used in producer programs. These usually contain measures of CP, some form of available energy, and mineral and dry matter concentrations. For example, the University of Florida program relies on a "Quality Index" (QI) to express intake of digestible energy as a multiple of the total digestible nutrient (TDN) maintenance requirement (Moore et al., 1984). In this program, NIRS is used to predict CP and NDF as percentages of DM, and in vitro organic matter digestion (IVOMD). Then appropriate formulas are used to convert NDF and IVOMD to TDN as a percentage of DM, as well as to calculate QI.

The QI was specifically developed for Florida tropical grass hays because the hay standards discussed earlier are based on temperate perennial forages and are not applicable to tropical grasses. It estimates ultimately the expected voluntary intake of TDN if the forage is fed free-choice and alone. Quality Index is expressed as a multiple of the animal's TDN requirement for maintenance, so that a QI of 1.0 indicates that the forage would support maintenance of a dry beef cow. Instead of a hay grade, QI assigns a numerical value to a forage which estimates whether it meets the TDN intake requirements of a specific class of animal.

The Hay Auction

A number of states are regularly using mobile NIRS systems to evaluate quality of hay at local or regional auctions. The usual response to this program has been an improvement in prices for top quality hay and a substantial increase in subsequent testing and selling of hay based on quality. For example, the number of auctions in Wisconsin at which hay was tested for quality rose from one to 98 during the four-year period after NIRS tests first became available (Figure 3; Rohweder and Vilstrup, 1985). The average price for hay sold by grade (based on RFV) at these auctions ranged from \$117 per ton for "prime" to \$68 or less per ton for grades 3 and lower (Figure 4; Rohweder and Vilstrup, 1985). The correlation between price and RFV was $r=0.58$, and sellers received \$1.05 for each point increase in RFV for stages of hay maturation earlier than full bloom (greater than grade 3). Similarly, in Minnesota auctions, hay prices ranged from a high of up to \$132 per ton for prime grade to \$52 per ton or less for grades 3 and lower (Linn, 1985); the correlation between price and RFV was $r=0.80$.

Testing will not always raise the price of hay sold, and it may sometimes result in lower prices (Bushnell, 1985); however, it will make hay prices more equitable to both buyer and seller.

The Educated Management Decision, Balanced Ration, And Resulting Profit

The objective in management decisions regarding forage utilization is to determine the quality and quantity of forage categories available and then to use the various categories in feeding animals relative to their needs to insure maximum profits. If a farmer had two hay lots, one that tested 144 RFV and another that tested 100 RFV, he could expect varying animal response and profit depending upon how he used these hays relative to the production potential of individual cows in his herd (assuming sufficient protein and energy supplements also were fed). If we assume:

Case A—the cow has genetic potential to produce 15,000 lb. of milk per year; and

Case B—the cow has genetic potential to produce 20,000 lb. of milk per year; then feeding the 100 RFV hay would be wise in case A because the cow's nutritional needs could be met, and she would produce essentially no more by feeding the 144 RFV hay; however, feeding the 144 RFV hay would be wise in case B because this cow's nutritional needs could not be met by rations containing the 100 RFV hay (she would produce only 15,000 lb. of milk per year if fed it), and she requires the 144 RFV hay to produce her genetic potential of 20,000 lb. Therefore, if the farmer has more 144 RFV hay than is required for his 20,000-lb-potential cows, he should sell the hay at an equitable price to his neighbor who has 20,000-lb-potential cows that can benefit from it rather than feeding it to lower-producing animals. This recommendation is based on our assumption that we currently have more 20,000-lb-potential cows in production systems than there is 144 RFV hay to meet their needs.

The farmer who participates in a forage testing program will ask new questions that will lead to increased production efficiency. An example is the farmer at a recent Minnesota hay auction (NIRS quality-tested) who found that his hay had a RFV of 120, but CP of only 11%. Upon the farmer's questioning of the results, the hay was examined and determined to be mostly very leafy orchardgrass that had not been fertilized with nitrogen. The farmer was instructed by the extension specialist that N fertilizer would have increased both the CP concentration and yield of his hay crop. We predict that next year this farmer will either fertilize his hay field with N or renovate to establish legumes to furnish hay that meets both the protein needs and the RFV needs of cattle owned by local hay buyers.

Extension specialists at the University of Wisconsin have reported considerable improvements in farmers' understanding of forage quality due to participation in a NIRS analysis program (Table 2). Positive actions included 40% more use of ration balancing for dairy

herds and 84% increased crop management modification. Increased profits were reported in 87% of the cases. Milk production per cow in herds of farmers who participated in the NIRS forage analysis program usually increased; 88% of the herds experienced at least 800 lb more milk per cow per year, and 33% of the herds experienced at least 2,400 lb more milk per cow (Table 3).

Wisconsin workers also reported improvements in efficiency of dairy ration balancing programs associated with tests of forage quality enabled by NIRS (Table 4). Mean increased profit per cow in 100 herds was about \$100 per year.

Yet to be determined is which quality levels of hay and other forages are so low that they prevent economic feed use for specific classes of ruminants. Often forage growers don't know their production cost, or if they do it is on a per acre rather than a per ton basis. To evaluate alternative uses for forage crops, the production cost per ton is needed. Then one can calculate the feed value per ton (via forage quality testing) and ultimately the return per ton. In this way, the farmer can determine whether he will save by purchasing less concentrates and whether he will profit by feeding vs. selling his hay.

Rohweder (1985) listed the following impacts that resulted from NIRS analysis of forage quality by dairy farmers: (1) increased awareness of forage quality; (2) improved crop and animal management; (3) more accurate, precise, rapid, low cost, and accessible forage analyses; (4) more precise ration balancing schemes; and (5) increased profits. He stated that "NIRS analysis has helped farmers take charge in these changing times". That sums up the present for progressive dairy farmers---but, the future of forage quality evaluation rests in the creative extension of present and future testing procedures and information to all ruminant animal production systems because all of these systems rely heavily on forage as the primary feed.

SUMMARY

"Forage quality" encompasses numerous traits, but two universal factors are nutritive value, which requires some expression of digestible energy, and potential intake by the ruminant animal. Four categories of laboratory methods have been developed to evaluate forage quality. A revolutionary new procedure that has great potential for analyzing chemical composition and associated forage quality traits is near infrared reflectance spectroscopy (NIRS).

The concept of relative feed value, which includes expressions of both digestible dry matter and dry matter intake, has been effectively used in forage evaluation, hay marketing, and ration balancing systems. New National Alfalfa Hay Testing Association Standards require expressions of estimated digestible dry matter, crude protein, and dry matter as minimum values. NIRS has been accurately used in essentially all of the current forage evaluation schemes and has allowed auctioning of hay on the basis of its feed value.

Educated management decisions depend on knowledge of quality of forages being fed to different classes of livestock. Those producers who have become knowledgeable about forage quality and testing invariably develop more efficient forage production and utilization programs and increase their profits. The future of forage quality evaluation depends on the creative extension of present and future testing procedures and information to all types of ruminant animal production systems.

Literature Cited

- Adams, R.S. 1984. Use of NIR, a rapid computerized forage testing method. p. 15-19 In Proc. 9th Annual Minnesota Forage Day. Minnesota Forage and Grassl. Coun., St. Paul.
- Ballweg, M.J., D.A. Rohweder, and W.T. Howard. 1985. Personal communication, University of Wisconsin, Madison (from presentation by Rohweder at 1985 Amer. Soc. Agron. Symposium on Transfer of NIRS Technology).
- Barnes, R.F., and G.C. Marten. 1979. Recent developments in predicting forage quality. J. Anim. Sci. 48:1554-1561.
- Bushnell, J.L. 1985. Hay marketing. Results of questionnaire reported at the Invitational ECOP Workshop on NIRS, November 13-15, 1985, Madison, Wisconsin.
- Fonnesbeck, P.V. 1985. Personal communication, Utah State University, Logan (from presentation at 1985 Amer. Soc. Agron. symposium on National Alfalfa Hay Standards).
- Jorgensen, N.A., W.T. Howard, and D.A. Rohweder. 1985. Forage analysis, terms, measurements, usage. From paper given at the Invitational ECOP Workshop on NIRS, November 13-15, 1985, Madison, Wisconsin.
- Linn, J. 1985. Four county forage councils sponsor hay auction. p. 3 and 5. In Minnesota Forage UPDATE, Vol. X, NO. 2, spring, 1985. Minnesota Forage and Grassl. Coun., St. Paul.

Marten, G.C. 1981. Chemical, *in vitro*, and nylon bag procedures for evaluating forage in the USA. p. 39-55. In Forage Evaluation: Concepts and Techniques. Proceedings of a Workshop held in Armidale, New South Wales, Australia in November, 1980. CSIRO and American Forage and Grassl. Coun.

Marten, G.C. 1985. Factors influencing feeding value and effective utilization of forage for animal production. p. 52-58 In Papers for Plenary Sessions, XV International Grassland Congress, Kyoto, Japan.

Marten, G.C., J.S. Shenk, and F.E. Barton II, editors. 1985. Near infrared reflectance spectroscopy (NIRS): Analysis of forage quality. U.S. Department of Agriculture, Agriculture Handbook No. 643, 96 p.

Martin, N.P., D.A. Schriever, G.C. Marten, and F.R. Ehle. 1984. Use of near infrared reflectance spectroscopy (NIRS) to analyze forage quality of alfalfa grower samples. p. 223-227. In Proc. 1984 Forage and Grassl. Conf., American Forage and Grassl. Coun., Lexington, Kentucky.

Moore, J.E., W.E. Kunkle, K.A. Bjorndal, R.S. Sand, C.G. Chambliss, and P. Mislevy. 1984. Extension forage testing program utilizing near infrared reflectance spectroscopy. p. 41-52. In Proc. 1984 Forage and Grassl. Conf., American Forage and Grassl. Coun., Lexington, Kentucky.

Rohweder, D.A. 1984. Wisconsin's NIR and hay marketing projects---a progress report. p. 1-12. In Proc. Wisconsin Forage Coun. 8th Forage Production and Use Symposium, Wisconsin Forage Coun., Madison.

Rohweder, D.A. 1985. Personal communication, University of Wisconsin, Madison (from presentation at 1985 Amer. Soc. Agron. Symposium on Transfer of NIRS Technology).

Rohweder, D.A., and R. Vilstrup. 1985. Progress Report: Quality Tested Hay Auctions ---1985-86. University of Wisconsin, Madison.

Subcommittee on Laboratory Certification of the U.S. Alfalfa Hay Quality Committee. 1984. Hay Testing Laboratory Certification Manual, Public. No.2. National Hay Assoc. and AFGC. (available from H.D. Gates, Jr., The National Alfalfa Hay Testing Association, P.O. Box 1059, Jackson, MI 49204.

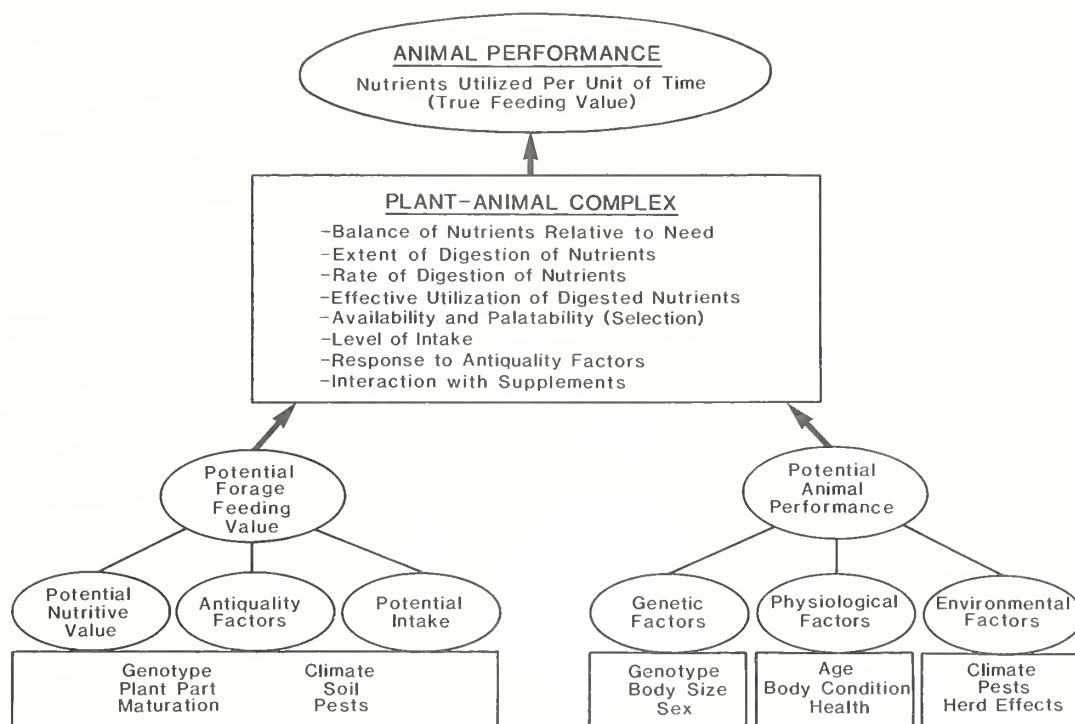


Figure 1. Plant and animal factors that influence feeding value (quality) of forages. From Marten (1985).

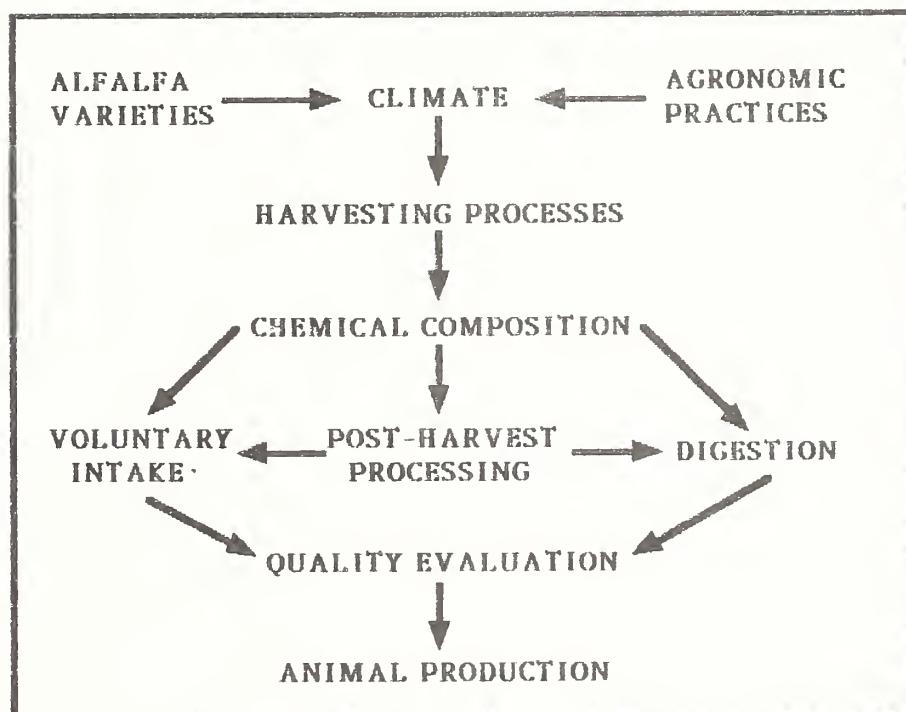


Figure 2. Factors that influence alfalfa hay quality. From Fonnesbeck (1985).

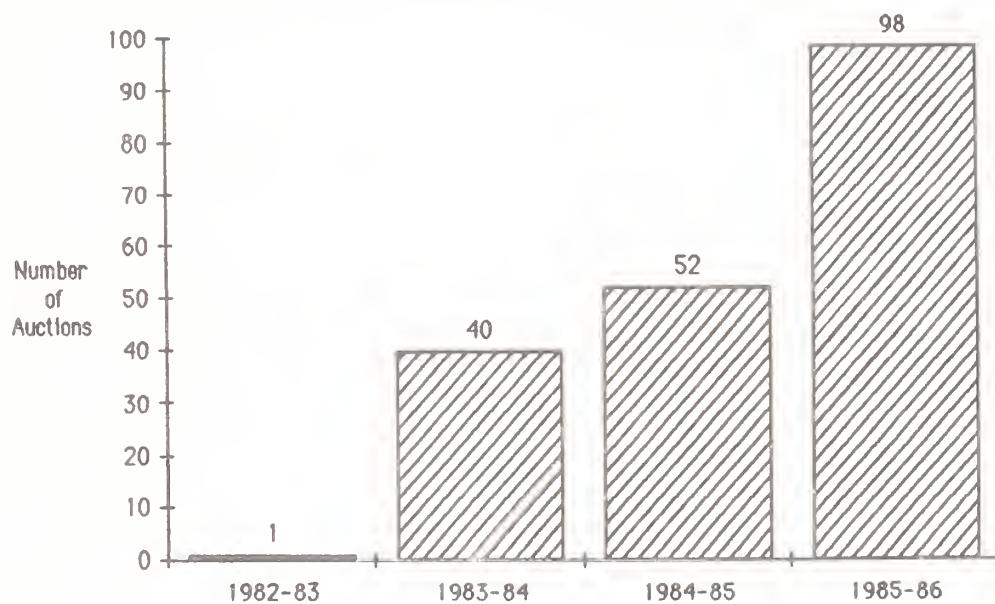


Figure 3. Growth during four years of Wisconsin auctions at which hay quality was tested by NIRS (Rohweder and Vilstrup, 1985).

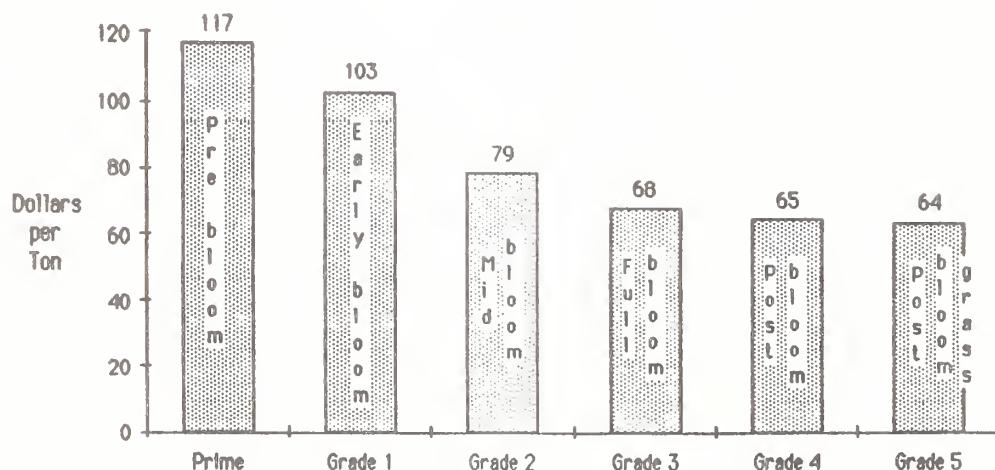


Figure 4. Average price per ton of hay sold on a relative feed value (grade) basis in two years at Wisconsin auctions (Rohweder and Vilstrup, 1985).

Table 1. Market Hay Grades for legumes, legume-grass mixtures, and grasses---AFGC
Hay Marketing Task Force ("A continuum from ^{a/}legume pre-bloom to grass
headed and/or heavily weathered forage"). ^{a/}

Grade	Species and stage	Description ^{b/}				
		CP	ADF	NDF % dry wt	DDM	RFV
Prime	Leg.-PB1	>19	<31	<40	>65	>143
1	Leg.-EB1, 20% grass-V	17-19	31-35	40-46	62-65	127-143
2	Leg.-MB1, 30% grass-EH	14-16	36-40	47-53	58-61	114-126
3	Leg.-FB1, 40% grass-Head	11-13	41-42	54-60	56-57	98-113 ^{c/}
4	Leg.-FB1, 50% grass-Head	8-10	43-45	61-65	53-55	86-97
Fair	Grass-Head, and/or Rain Damaged	<8	>45	>65	<53	<86
6	Sample					

^{a/}Description adopted by U.S. Alfalfa Hay Quality Committee.

^{b/}PB1=Pre-bloom, EB1=Early-Bloom, MB1=Mid-bloom, FB1=Mid-to-full-bloom,

V=Vegetative, EH=Early-Head.

^{c/}Reference hay, mid-to-full-bloom alfalfa, as RFV=100.

Adapted from Jorgensen et al. (1985).

Table 2. Improvements in Farmers' Understanding of Forage Quality Due to Use of a NIRS Analysis Program (Ballweg, Rohweder and Howard, 1985).

<u>Factor that was improved</u>	<u>Percentage increase in comprehension or action</u>
Comprehension of forage dry matter & crude protein	95
Knowledge of effect of dry matter on silage quality and of cutting schedules on forage quality and yield	74
Comprehension of acid detergent fiber as a predictor of digestibility and of neutral detergent fiber as a predictor of intake	40
Crop management practices	84
Use of ration balancing	40
Increase in net profit	87

Table 3. Extent of Improvement in Milk Production Per Cow (Increase in Rolling Herd Average) in Wisconsin Due to Use of a NIRS Forage Analysis Program (Ballweg, Rohweder and Howard, 1985):

<u>Increase in milk (lb/cow/year)</u>	<u>Percentage of herds that showed response</u>
None	10
800	40
1600	15
2400	18
3200	15

Table 4. Improvements in Efficiency of Dairy Ration Balancing Programs Associated with Tests of Forage Quality in Wisconsin (Ballweg, Rohweder, and Howard, (1985)).

<u>Efficiency Factor</u>	<u>Improvement pre-NIRS when crude protein was emphasized (1978)</u>	<u>Improvement post-NIRS when digestibility & intake were emphasized (1984)</u>
Increased milk/cow	67%	96%
Decreased cost of purchased feed	70%	83%
Decreased amount of grain fed	14%	68%
Increased amount of grain fed	12%	32%
Increased profit/cow	\$80	\$100
Increased profit from 100 herds	--	\$500,000/yr

THE DAIRY INDUSTRY AND ITS FUTURE

D.R. Mertens¹

INTRODUCTION

Current State of the Industry: The dairy industry is facing a period of tremendous change. Milk production has exceeded demand for many years; however, the federal government has recently decided not to maintain the status quo by purchasing the excess milk produced. It is clear that the long term solution for stabilizing the industry is to balance milk production with milk demand. Many approaches to the problem of production/demand imbalances have been developed. Only a few comments about the industry-wide dilemma will be given. The primary focus of this presentation will be the potential role that forage production and use can play in the survival of individual dairy farms.

In many ways, dairy farmers are victims of their own success. Since the late 1970's dairy farming has been a bright spot in the agricultural income sector. Profitable dairy enterprise budgets and monthly income generation led many lenders to encourage new farmers to establish dairies as a means of handling large debt loads. Many established dairymen expanded dairy operations to accommodate cash flow shortfalls associated with increased capital expenditures. While the number of dairy farms decreased, the annual decline in cow numbers stopped in 1979. Increased cow numbers combined with increased production per cow has resulted in excess milk production. It is clear that the dairy industry's ability to produce milk can and does exceed demand. Reducing the price of milk will cause economic forces to bring production and demand into balance. However, this will not be accomplished without suffering by both efficient and inefficient producers.

An alternative solution is to stimulate demand. Dairy farmers have been encouraged to stimulate demand via promotion and product development. Although increasing demand is a laudable goal, the gains appear to be small with long-term payoffs. There is an inelasticity in food demand associated with the inelasticity of the human stomach. Dairy product consumption can increase only at the expense of other food items. Since 1970, dairy products have comprised a relatively stable 20 to 24% of American food consumption. It appears the major increase in demand will be associated with increases in population rather than increases in per capita consumption of dairy products. However, increases in population should result in a gradual increase in demand for dairy products in the future.

¹Research Dairy Scientist, USDA-ARS, U.S.
Dairy Forage Research Center, Madison, WI
53706

It appears that fluid milk demand will continue to decline unless adults can be convinced that milk is a healthy component in their diet. Milk is consumed primarily by children, while adults traditionally consume more carbonated beverages and beer. It is difficult to envision that adults will be convinced to drink milk as a beverage in place of soft drinks. Few adults think of milk as a thirst quencher after a game of racquetball or long afternoon in the hayfield. Perhaps milk should be promoted to adult audiences on the basis of its health promoting properties. Milk supplies calcium, a mineral needed for bone strength especially in older women. Calcium also has been associated with reduced heart disease. Lactose promotes lower bowel acidity and may be important in intestine health and function. If each adult in America drank a single glass of milk each day (whether whole, 2% or skim) the demand for milk would increase dramatically and the health of the average adult would be improved.

Before addressing the main theme of this presentation, it is important to address one last topic the dairy industry must face regarding production and demand. Americans do not demand fat. Why are we still encouraging fat production by an outdated method for pricing milk? Pricing milk based on volume and total solids would appear to be more rational. Pricing on fat content forces dairymen to strive against their industry's best interest. Is the dairy industry being served by continuously selecting and breeding dairy cows that produce more fat?

Forages - Key to Future Dairying: Forages can and will play a critical role in the survival of individual dairy farms. The role of the majority of dairy cows in the United States (those located in the Northeast, Midwest and North Central regions) is to convert forage crops grown on the farm into a salable commodity - milk. Even in areas of the country where most feed ingredients are purchased, such as the West, Southwest and Southeast, a majority of the ration is forages or fibrous by-product feeds that have little value unless converted to milk. Too many dairymen and their advisors have not realized that the function of a dairy cow is to convert the product of the farmer's land, forages, into cash income. Too much emphasis has been placed on feeding grain to maximize milk production without realizing that the goal is to maximize returns from the land. Once it is recognized that the cow is the manufacturing plant which converts the forage raw material into a salable product, it is easy to understand that management of both the plant (cow) and the raw material (forage) are equally important.

Forages have both positive and negative effects on dairy cow performance which influence the amount of forage that can be fed. Minimum forage is needed to meet the roughage value requirement of cows. Roughage value is associated with the chewing activity needed to

reduce feed particles to a size that can pass through the digestive tract. Chewing activity is important to the dairy cow because buffers in the saliva that is produced during chewing regulate acidity in the rumen. Salivary buffers help maintain a rumen environment that optimizes rumen fermentation and health. The negative aspects of forages as feed ingredients are related to their lower energy content than concentrates and their bulky nature which tends to limit feed intake. Survival of individual dairy farms in the future will depend on the optimum production and feeding of forages. If too little forage is fed, off-farm feed inputs become excessive and cow health suffers. If too much forage is fed, feed intake and energy content are reduced and cow productivity declines. Dairymen of the future must insure that high quality forages are grown, harvested and fed properly in order to maximize the return from their cows and land.

1. Growing Forages. Much of the land located on dairy farms in the United States is not suitable for cash crop production. Forage production on this land is logical both from the standpoint of conserving soil resources and obtaining maximum productivity from the land. However, it is important to match the forage type grown with soil characteristics. There is no single best forage for dairy cows in all situations. Many forages can be used to obtain profitable production if managed and fed properly. It may not be profitable to attempt to modify some soils by excessive lime, fertilization, and drainage systems in order to grow a specific crop such as alfalfa. Alfalfa is an excellent forage for dairy cows, but if it requires excessive inputs to grow alfalfa on a specific farm it may not be the most profitable forage to produce and feed. In the future it will be critical to select forages that fits the soil and climate of each farm then feed them optimally.

As a part of a program to minimize outside inputs, more attention will be needed in optimizing the use of recycled wastes. Energy prices will eventually begin their upward spiral. As they do, fertilizer costs will become a significant factor in the cost of forage production. Soil testing, combined with a plan for retaining and distributing wastes to maximize the recycling of forage nutrients, will become important components in forage production. Livestock manure should be considered a resource to use in maximizing farm returns rather than a waste to be removed. Like any fertilizer, it should be applied based on soil condition, crop requirements and timing.

2. Minimize Harvest and Storage Losses. Too many forage nutrients are lost between the time forages are grown and fed. Perhaps because it is not viewed as an out-of-pocket expense, many dairymen are willing to accept 15 to 35% loss of nutrients that are grown. Convenience and lack of proper planning and harvesting management are

often the culprits that steal too much forage quality. In the future, forage types and varieties will be selected to spread the harvesting time over an interval that will insure that the proper maturity is harvested for all forages. At present, too many farms grow one type and variety of forage which is harvested over a three to four week interval; thereby insuring that much of it is harvested at maturities beyond optimum quality. Management systems which use fertilizer applications, north/south slope exposure, grazing or clipping systems and alternative harvesting systems to spread the optimum maturity time frame at each cutting are needed. Systems are also needed for harvesting and storing each maturity and quality so it can be used most effectively.

Most of the nutrient loss in forage production is related to harvesting and storage losses. Many forage producers willingly accept harvesting losses of 25% while grain producers are concerned about 2 or 3% losses during harvest! Most producers are worried about weather damage as the main loss; however, in terms of total nutrients lost between standing crop and feed bunk it may be one of the smallest losses. Too many leaves are left on the ground or blown out of the wagon by raking, baling or chopping forage that are too dry. Equipment is needed that gently moves forages as it is harvested. More farmers in the future will be using desiccants and preservatives to speed drying and permit forages to be harvested at higher moistures so that field losses are minimized.

The antithesis of producing quality forages is the large round bale. At best it causes a 15% loss of nutrients and often losses are near 40%. Isn't this price too high for convenience? Would most dairymen accept 40% losses of their corn crop as willingly? Although it is clear that labor intensive haying operations must be improved, loss of more than 10% of the nutrients grown will not be acceptable in the future. Similarly, the losses associated with heat damaged protein in low moisture silages cannot be tolerated. Silage production systems must insure that the nutrients removed from the field are fed to the cow. Losses in the silo due to deterioration as well as heating are a double loss. Not only are nutrients lost, but also the labor, energy and wear on equipment used to harvest and transport the nutrients to the silo are lost. New technology will be developed that allow silage and hay harvesting in a 24 to 36 hour period thereby minimizing weather and field losses of nutrients.

3. Allocation of forages. No matter how well planned, the weather, mechanical problems and forage differences will insure that all forage harvested will not be a constant, high quality. In order to maximize forage use, highest quality forages must be fed to the dairy cows with greatest nutrient requirements. Dairymen of the future will realize that quality differences among forages can be almost as great as the

difference between forages and concentrates. Few dairymen feed the same amount and type of grain to all cows in a herd, yet forages are often fed indiscriminately. Systems for inventorying and allocating forages are needed. This problem is greater for silage based systems because the number of units and order of feeding are locked in. However, as facilities are updated or expanded, dairymen of the future will use more storage units of smaller size to allow optimal storage and allocation of the various qualities of forage that are harvested.

4. Forage Analysis. There are many excuses for not analyzing forages (too costly, too slow) but none of them are valid. It is difficult to maximize the use of forages and minimize the fluctuations in milk production that occur with changes in forages without nutrient content information on the specific forages to be fed. When used to formulate rations, forage analysis doesn't cost, it pays. It is all too common for cows to drop 2 to 4 lbs. of milk per day when forages are changed and ration adjustments are not made. The cost of feed analysis can easily be paid with one or two days lost milk. Conversely, properly balanced rations can easily result in 2 to 4 lbs. additional milk per cow or \$.02 to .08 less daily feed cost per cow. These returns can easily yield \$1 to 3 for each dollar invested in forage analysis. New technology such as near-infrared reflectance spectrophotometry and new chemical methods such as neutral detergent fiber (NDF) will provide the means for more rapid, less expensive and more useful forage analysis information. Since the NDF system separates feeds into digestible neutral detergent solubles and less digestible NDF, it provides an accurate way of comparing all feeds. For example, brewers grains, early maturity alfalfa hay and corn silage have approximately the same NDF content, yet conventional wisdom would call one a concentrate, one a forage and one a 50:50 forage:concentrate mixture. The NDF system indicates they have relatively equivalent feeding value for dairy cows if particle size differences can be ignored.

Since fiber is related to all of the major characteristics important in forage quality (roughage value, energy content and intake limitation), fiber content is a critical component of forage analysis.

It has been recognized for many years that crude fiber (CF) does not measure all the fiber constituents in forages. Lignin, an indigestible fiber component, is partially dissolved by the CF method and is not measured as fiber. Hemicellulose, an incompletely digested structural carbohydrate is also dissolved in the CF method. Acid detergent fiber (ADF) has been proposed as an improved fiber measurement system because it retains all the lignin in the ADF fraction. However, hemicellulose is dissolved by acid detergent. This causes discrepancies in comparing fiber values of feeds which differ in hemicellulose

content, such as grasses and legumes. Neutral detergent fiber measures all three fibrous constituents: cellulose, lignin and hemicellulose. The non-NDF, or neutral detergent soluble (NDS), part of the feed contains the proteins, sugars, starches and fats which are almost completely digestible.

5. Formulating Rations to Maximize Forage Feeding.

At present, too much grain and concentrates are fed in relation to the milk production obtained. It is not uncommon to observe farmers feeding 5-6000 lbs. of concentrates in herds with 14,000 lb. herd averages. Too many recommendations for feeding dairy cows have not kept pace with changes in forage quality. As little as 15 years ago, excellent alfalfa hay was described as containing 15-17% crude protein (CP). Today, many farmers are harvesting alfalfa that contains in excess of 20% CP. Fifteen years ago it was necessary to feed 20 lbs of concentrates to cows producing 60 lbs. of milk; however, with today's high quality hays, 12-15 lbs. would be adequate. For years, dairymen have been extolled to feed more grain and improve forage quality in order to achieve more profitable dairy production. They have done both, but doing so has not maximized the use of high quality forages. Dairymen and their advisors need to recognize that high quality forages can substitute for concentrates and that overfeeding grain results in inefficient use of high quality forages.

Old guidelines recommended that high producing cows be fed diets containing 50 to 60% concentrates. This is valid for forages containing 12-15% CP and 50-60% NDF, but not for those containing 18-22% CP and 40-50% NDF. A classic example of overfeeding grain involves the use of corn silage. Typically, corn silage is fed in rations with 50:50 forage:concentrate ratios. Since corn silage contains 50% grain, in reality the typical forage:concentrate ratio is near 25:75. This is higher than necessary for dairy cows, even when the low quality of the corn stalks is considered. Most corn silage based rations could be used more efficiently if concentrate ratios were reduced and the protein content of the concentrate increased.

New systems of formulating rations are needed that can more accurately establish the correct ratio of forage:concentrate to be used when a specific forage is fed to a specific group of cows with a given level of milk production. Intake becomes the limiting factor which establishes the maximum amount of forage which can be fed and still meet nutrient requirements. The fibrous nature of forages limits the cows' ability to consume them. Recent research suggests that NDF can provide the basis for future systems for formulating dairy rations.

The NDF content of forages is related to their energy content and intake potential. By combining NDF analysis of the forage with the nutrient requirements of the cow for a target

level of milk production, the NDF system can predict the forage:concentrate ratio and NDF content of the ration and the dry matter intake of dairy cows that maximizes forage intake and achieves target milk production. For example, in order to produce 60 lbs. of 3.5% milk using a ground shelled corn and soybean meal mixture with a forage containing 65% NDF, the forage concentrate ratio that maximizes forage intake would be 46:54. However, if the forage contained 45% NDF, the forage:concentrate ratio which maximizes forage intake would be 71:29.

6. Using Fibrous By-Product Feed Ingredients. Dairymen in the future will capitalize on the dairy cow's unique ability to use fibrous feeds. Many by-products of the beverage and food industries provide valuable opportunities for dairymen to purchase off-the-farm feed inputs economically. Many of these feeds which include; distillers' grains, stillage, brewers' grains, gluten feeds, citrus pulp, beet pulp, almond hulls, cottonseed and soybean mill feed; have unique properties. Some provide a highly digestible fiber source that can be used to reduce the starch content of the ration. Others provide slowly degradable proteins which can escape rumen fermentation and be absorbed directly by the cow. In the future, these feeds will provide a lower cost alternative to grains in dairy cow rations.

Non-Forage Factors Important to the Future of Dairying: Although forage management will play a crucial role in the dairy industry of the future, many other factors will need superior management in order for dairymen to survive. Financial management will be critical to insure that there is sufficient net income to service debt and yield a return for labor and investment. Greater control over capital expenditures will be important as inflation rate and interest rates begin to climb in the future. Records of all types; financial, cow health and reproduction, DHI, soil and crop, etc; will be the keys to making decisions that will be profitable and flexible. New computer technology will become available using expert systems that will help farmers analyze and interpret the records he keeps. Records that are not used are worthless!

More dairymen should be using artificial insemination. There is no excuse for not capturing the genetic gain that is provided by sire summaries and sire selection programs. New forms of genetic manipulation such as, embryo freezing and transfer, and cloning, will become available for augmenting the genetic gain in milk production we can achieve. However, much of the genetic potential of dairy cows is not tapped at present, and first priority should be given to proper cow care and feeding management that will allow us to benefit from the genetic material on hand.

New technology such as growth hormone and feed additives will become available. Much concern has been expressed about the impact of these

products on the dairy industry. Growth hormone is especially exciting because of the potential increases in production it elicits. I suspect that the reality on the farm will be different from the research in the laboratory. Unfortunately, growth hormone does not allow the cow to create milk out of nothing. Like other products such as thyroprotein, growth hormone will stimulate additional requirements for nutrients as milk production is increased. This will place even more stress on the importance of high quality forages and accurately formulated dairy rations.

Conclusions: Forages will be the key to survival for dairymen in the future. Most dairy cows are used on farms where their role is to convert the forage produced on farm land into a saleable product. In the future, new technology and the cost-price squeeze will place additional stress on the production and utilization of forages and fibrous by-product feeds. Greater care will be needed in the future to insure that forages are grown, harvested, stored and fed with a minimum of losses. Forage is a valuable product on most farms which deserves optimal management and utilization.

GRASS - THE NEXT CINDERELLA CROP

H. Allan Nation

Agronomists all over the United States are scanning the horizon for the next Cinderella crop to hit American agriculture. In the 1970's the Cinderella crop in much of the U.S. was the soybean, but today with fearsome competition arising in the Southern Hemisphere the soybean looks more and more like the Wicked Stepmother to farmers who grow it. Corn, wheat, cotton and rice are all in gross oversupply in the United States, and few expect a dramatic turn-around in the demand for any of those U.S. crops in the remainder of this decade.

I hope to be able to make a credible case that America's Cinderella crop for the remainder of this century is all around you. It is here and has always been here and that crop is grass.

The Good Lord in his magnificent plan for the universe has deemed grass to be the ultimate climax crop in his universe. He absolutely will not allow a bare piece of ground. Grass cools the soil, tempers the fall of the raindrop, and heals and rebuilds the soil, organic matter and nitrogen. Grass is the only crop we can grow that puts more into the soil than it takes out of it.

The stirring and tilling of the soil and the planting of monocultures is not found naturally anywhere on earth. These activities eventually destroy the organic matter God's grass crop carefully built in the soil and will economically destroy the farmer eventually. Without organic matter, the soil's lifeforce of microbes dies, and when the life dies in the soil crop residues will no longer recycle. Herbicides will no longer work and can actually do more damage than good. The soil has no water holding ability and the soil will eventually literally blow in the wind.

In the Mississippi Delta, farmers are having to almost continuously run center pivot irrigators to grow cotton in a 60 inch rainfall area. The soil has so little organic matter that it can only hold one-half an inch of water in an area where the summer daily evaporative rate is one-third of an inch. The only thing that can break the death spiral for these farmers is to put this land back to grass for four or five years and heal the soil. Unfortunately, many of these farmers were able to get a degree in agriculture with virtually no understanding of soil science or ecology. They, in their ignorance, still believe that cotton is king and grass is something you try to kill.

These farmers, who are going broke by the bushel basket, will tell you their land is too good for grass and yet any soil scientist can tell them that their land has been rendered virtually worthless by their continuous cropping. Research in Georgia shows a virtual doubling of yields for any subsequent crop grown behind five years

of a sodgrass, and yet 75 to 80% of the chemicals used in American agriculture are sold to kill grass.

There is a reason why these farmers are going broke, and it has less to do with prices and export markets than it does with ignorance of the basics of soil science. Why was this allowed to happen? The base reason was money. The whole research and communications establishment of American agriculture sold out to the boys who had money, which were the chemical and fertilizer companies. Farm magazine publishers realized the big bucks were those double-page spread herbicide ads. Researchers realized the big bucks were in ridiculous product A versus product B product testing rather than trying to figure out how not to use either product A or product B.

Any of you who get any free farm magazine or any farm magazine with a ridiculously low per year price need to realize that magazine is working primarily for his advertisers. You also need to realize that a lot of the research information you read was bought and paid for by some chemical company. I am not saying that any of this information is false, but that all of it is skewed toward the use of greater petrochemical inputs rather than rotation, diversification and working in harmony with nature.

I don't have to tell any of you what has been the result of this shift to petrochemicals and high capitalization. You can see the results in your community as well as on the evening news every night. Anyone who bought this line from the Federal Land Bank to International Harvester is sick and near death.

The reason people are starving in Ethiopia is because a society built on grass and nomadic sustainable grazing bought the whole boat of modern agriculture and shifted to unsustainable rowcrop agriculture. There has never been a civilization in history that has been economically sustainable based around rowcrop agriculture, whereas civilizations based upon grazing have existed for thousands of years.

It is not hard to sell the idea that rowcrop farming is not profitable today. What is difficult is to sell the idea that grass is probably the most profitable crop a farmer can grow in 99 cases out of a hundred. Our problem has been that we have not looked at grass as a crop and ourselves as grass farmers. Animals are merely the combines for the crop. No rowcrop farmer would ever use a corn header to harvest wheat and yet we mismatch animals and their environment with little thought. Too many of us describe ourselves as cowmen, or sheep men, or yearling operators with too little thought about whether our environment matches our animal decision.

In much of the United States, the grass growing season is only 60 to 100 days long and snow covers the ground for six months or more. Such environments do not lend themselves to year-round cow-calf production nearly so well as

seasonal stocker operations. In much of the United States, combinations of species and classes of animals offer a much better harvest than any one species or class. All of our grasses have seasonal protein requirements high enough to allow our grazing animals to breed and our breed-seasons must mesh with these periods.

We have placed entirely too much emphasis on weaning weights and not nearly enough emphasis on genetically matching animals and their environments. For example, much of the Southwest is covered with brush and yet there are cattle in Africa who can make up 90% of their diet from brush. It would be much more cost-effective to genetically adapt the cattle to the brush than to chemically adapt the environment to our present breeds of cattle.

There will never be one "ideal" steer in the United States. Genetics will have to be altered to allow the animals to maximize the harvest of the existing environments. The correct emphasis for any cowman is not on the steer calf but on the replacement heifers he is carefully adapting to his specific environment. Genetic adaptation comes not so much from the bull we buy, but the cow we cull. The more ruthless we cull, the faster we adapt our herd. A 75% calf crop indicates that we are three-quarters of the way there in getting rid of cows who can't hack it under our environment.

Our customers, the American consumers, are telling us to route fewer animals to the feedlot and more to the hamburger stand. We need to allow every heifer we produce to have a chance to make it as a productive breeding animal that is better adapted to our environment than her mother. If she, in fact, proves she is so adapted, Momma goes to McDonald's and daughter takes her place. Those who say we have too many cattle in the United States totally overlook the fact that we import one billion pounds of hamburger grade beef a year. That's the slaughter equivalent of the entire cowherd of Missouri, our second largest cow-calf state.

Our post-weaning steer programs need to be re-gearred for producing animals in the 850 to 1000 pound weight category prior to being placed in the feedlot for a quick finish. Our critics point out that cattle are wasteful users of the grain resources of the world. Economists point out that cattle will never anywhere equal the feed efficiency of chickens, and both the critics and the economists are right. However, if we place cattle on feed at this weight category, the total feed efficiency of grain to liveweight slaughter equals or exceeds that of poultry. I'm not going to overly worry about poultry competition until they breed a bird that can gain two pounds a day on grass, and as far as a waste of our grain resources, I am far more worried about our waste of grass resources.

The central plains area was originally a summer fattening range for yearlings driven up from Texas and it worked extremely well as such. When

we started shifting the post-weaning growing program from grass to grain, we created a huge under-utilized resource. Man hates to see a resource go to waste, so we expanded the only part of the cattle business left to grass - the cow. This set us off on the roller coaster we have been on for the last 35 years, whereby the availability of grain rather than grass dictated the size of the cow herd. Every mouthful of grass a steer eats relieves the pressure to have that mouthful of grass eaten by a cow.

If we start routing cull cows to slaughter rather than heifers to the feedlot, and if we start growing all our steer production to 850 to 1000 pounds before placing them on feed, you can start to see that we could have a much better utilization of our grass resources without that much increase in total tonnage of beef. It would also largely free us from the grain market vagaries. We do not have cattle to eat surplus grain. We have cattle to harvest grass.

Let's look at the pieces of our puzzle so far. We've got a crop that God will grow for free. We've got a harvesting machine that runs on sunlight and water, but we've had one key element missing. That element was the ability to efficiently control and steer our harvesting combine. And, it was this one missing element that allowed row-crop farming to be more profitable than grazing.

Consider for example the economics of growing a crop, but having a combine aimlessly churning through the field during the entire growing season. It would be bad enough if this combine were only loosed to do its damage when the crop was ready to harvest, but I am talking about a combine that wanders aimlessly over the crop from the day the first seed is planted. Picture that please. Can you imagine how much of the crop would be crushed by the wheels of the combine compared to how much wound up in the hopper?

While this sounds totally ridiculous in the context of a soybean or corn crop, it is precisely how we have been attempting to harvest our grass crop. Our cows only harvest approximately one-third of the grass we grow with continuous grazing.

Our biggest problem in grassland farming has been that we have been attempting to grow more grass rather than attempting to more efficiently harvest what we have already grown. It is on this one key missing piece of the puzzle that all of our grassland economics have foundered, and it is on this one key piece of the puzzle we are starting to separate the men from the boys, and the winners from the losers, in the grass business.

In my opinion, the greatest technological breakthrough in the history of the cattle business has been these new New Zealand electric fences. As a boy, I grew up on a commercial cattle ranch, and I hated every minute of it. Looking back, it was not the cows I hated. It was those damned barbed wire fences that were always needing re-

pair. I recently visited a man in Alabama with 9000 head of cattle, and not one fence on his place was more than a one wire New Zealand style electric fence.

Fencing costs, which were the major capital cost of a grassland farming operation just a few years ago, are a minor expense now. Now for the first time, we can start effectively controlling that combine on our crop. Just like the rowcrop farmer, we can let our crop get to its optimum harvest stage and then whack it off with our combine. Then just like the rowcrop farmer, we can keep our combine off the crop until it is at its peak and whack it off again.

Like the cotton farmer, we can also pick and scrap. We can let our yearlings pick the prime crop and the cows follow them and scrap the rest. With control over our cattle, we can start effectively harvesting alfalfa, johnsongrass, orchardgrass, and other extremely high quality forages that were previously only harvestable as hay.

Rather than going to all the trouble of harvesting corn as silage, we can grow a corn crop, allow it to stand and dry down until we need it in the winter, and then take one of these reel-type electric fences and ration off only as much of the corn crop as our yearlings can eat that day. In effect, we can combine a rowcrop just like a grass'crop.

Want to fatten steers on grain sorghum? Stagger plant your crop and strip graze it while the grain heads are still in the soft, green, doughy stage. After you've gone across the crop like this approximately twice in much of the U.S., you'll still have an excellent standing hay crop to winter your dry cows on. Virtually any crop we can harvest with an oil-burning, iron combine, we can harvest with a solar-powered animal combine.

I hope I have shown you that all of the pieces of the puzzle are finally in place. All we need now are grass farmers willing to put these pieces together in their most optimum form for their particular area. If you'll forget the past, ignore prejudices and old wives' tales about cattle and grass, and if you'll start to think of grass as a crop and animals as a combine, I think you too will start to see that grass is indeed America's next and most enduring Cinderella crop.

1/ H. Allan Nation is editor of The Stockman Magazine in Jackson, Miss.

THE BEEF INDUSTRY AND ITS FUTURE

David G. Topel¹

ABSTRACT

The future of the beef industry can be very bright and consumption of beef can increase if the industry initiates programs which will greatly reduce production costs and market very lean, low calorie beef. Use of excellent forages in the production systems can help reduce production costs and also result in very lean beef for the consumer.

The tremendous amount of new technology which has been developed in recent years both for production and processing of beef provides some excellent opportunities for innovative industrialists who are willing to develop low fat, but quality beef products. The application of new technology from production through processing may be considered a high risk business by traditional people in our industry. People with a good business and management background, however, could easily take the existing technology and produce very lean and quality beef at much lower production costs than exist in our current system. An excellent forage system is essential for low cost cattle production. The timetable in which the technology will be incorporated into our system is unknown, but I would be surprised if much of this technology is not utilized on a commercial basis before the year 2000. I know that we have well established management personnel in the beef industry who are giving serious consideration to many of the concepts which were discussed in this paper.

We will see more changes in the beef industry in the next fifteen years than we have observed in the last forty. The consumer is demanding a different type of beef product than we've had previously. These demands will result in major changes in the livestock and meat industry.

INTRODUCTION

The livestock and meat industry has undergone some dramatic changes in the past thirty years. The industry has greatly reduced the total fat in the meat producing animals marketed in the United States. These changes are a result of the consumer demands for less fat and more lean meat in their diet. The poultry industry has made even greater changes. The poultry industry has used maximum genetic improvement combined with efficient production practices to produce high quality, but low fat poultry meat products for the American consumer. These practices have resulted in lower production costs for poultry

meat compared to the red meat industry. The tremendous improvements in efficiency of production by the poultry industry have resulted in much lower retail cost for poultry meat products and a major increase in consumer demand. Table 1 shows the per capita consumption of poultry meat products versus red meat products from 1960 through 1984. The per capita consumption of poultry meat and meat products has continually increased each year from 1960 to the present. A major shift in consumer preference for poultry meat compared to red meat was clearly reflected by the American consumer in 1982. In 1982 poultry meat accounted for 32% of the total meat consumption and a major increase from 1973. Beef, however, decreased from 1973 to 1982 (Table 1). The consumer trends which have occurred in the last ten years for lower calorie foods will continue to occur over the next decade. Therefore, the future of the beef industry will depend on its ability to develop more efficient production systems and market animals with considerably less fat.

Table 1. United States Consumption of Pork,
Beef and Poultry^a

	Year				
	1960-63	1970-73	1982	1983	1984
Pork	59.5	62.7	59.0	62.2	60.8
Poultry	36.8	49.6	64.1	65.4	66.0
Beef and Veal	71.2	85.3	78.8	80.4	80.6

^aExpressed in pounds.

We must not only be concerned about improving our efficiency of production, but we also must reduce the energy cost associated with our processing methods in the meat industry. Red meat processing, the most energy intensive of all the food industries, has become vulnerable to fluctuations in the energy supply. Further energy efficiencies, however, can be achieved through processing innovations and economic alternatives for energy utilization by the meat industry (Hendrickson, 1981). It is evident that our greatest challenge will be to improve the efficiency of production and processing techniques. Our economy will dictate this change to the industry and the competitive pressure from the poultry industry and non-meat protein sources will provide great competition in the next ten years for the beef industry. For the beef industry to be competitive in the year 2000, the ideal carcass will have considerably less fat than exists in the carcasses produced in 1985.

THE BEEF CARCASS CHALLENGE

The beef cattle industry has made great progress in reducing the fat in the Prime, Choice, and Good grade carcasses merchandised

¹Department of Animal and Dairy Sciences, Auburn University, Auburn, AL 36849.

for the retail industry (Table 2). The beef industry in the last three years, has greatly reduced the dollar value for yield grades four and five which represent the extremely fat beef carcasses. The cattle feeder merchandising overly fat cattle in 1985, could receive as much as \$120 less per animal as compared to trimmer cattle which represent the yield grade one through three. The severe discount for over finished cattle certainly will have an immediate impact on the cattle feeder to merchandise trimmer cattle.

Table 2. Carcass Yield Grading as a Percentage of Pounds of Graded Carcasses^a

Year	YG1	YG2	YG3	YG4	YG5
66	1.5	41.8	54.6	2.0	0.2
67	0.9	35.4	61.9	1.7	0.1
68	0.8	33.8	64.0	1.3	0.1
69	1.0	37.2	60.8	0.9	0.1
70	1.0	32.8	65.4	0.7	0.1
71	0.8	31.4	67.0	0.8	0.1
72	0.5	26.5	70.6	2.0	0.1
73	0.8	27.5	67.9	3.4	0.4
74	0.8	25.1	67.3	5.9	0.9
75	1.7	31.2	63.6	3.2	0.3
*76	1.9	28.4	57.5	10.3	1.7
77	2.4	30.9	57.2	8.3	1.1
78	2.2	30.4	58.3	8.2	0.9
79	1.8	28.9	58.8	9.3	1.2
80	1.7	28.9	58.3	9.7	1.4
81	1.9	30.4	57.1	9.4	1.2
82	2.3	35.9	54.6	6.6	0.7
83	2.5	36.3	54.3	6.3	0.7
**84	3.3	42.0	49.6	4.7	0.3

*Changes in the Beef Grades Standards which became effective in 1976 required that all carcasses quality graded also be yield graded

**7 month data.

^aData were obtained from USDA, May, 1985.

It is possible that the beef cattle industry will have more than one type of ideal carcass by the year 2000. I would anticipate a certain demand for high quality beef as it exist today. This type of beef will continue to be very expensive, but sufficient Americans will have the finances and desires to purchase this type of beef for their daily menu. I can also see another group which will prefer extremely lean beef which is practically devoid in marbling. This beef will be produced in production systems which emphasize forage rather than grain as a major component of the ration for beef cattle. I believe these production systems will continue to grow in number and we will have a gradual shift of the beef industry from the traditional feedlots to regions which can produce large quantities of forage without irrigation systems. This program would require the

development of new packing plants and the application of new technology in the fabrication of high quality and lean beef products by modern processing techniques. These methods can greatly reduce the cost of lean beef products at the retail level and provide a good margin of profit for all phases of the beef industry. By the year 2000, I would expect an increase in lean beef production and a decrease in the traditional grain fed beef industry which exists today. In the next 20 years, there may not be one ideal beef carcass, but several ideal carcasses which will meet the needs of a specific component of the consuming public in the United States. After the year 2000, I would project that the majority of the carcasses produced in the United States will be practically devoid in marbling and have approximately .1 inches of subcutaneous fat.

GENETIC BASE

The genetic base for the cattle industry is extremely variable. The incorporation of exotic breeds into the traditional English breeds used for many years in the United States has resulted in tremendous opportunities for the cattle producer to greatly improve the growth rate and reduce the fat in the cattle population of the United States. A large number of countries have selected for reduced fat and increased muscling many years before the U.S. cattle industry decided it should reduce the fat content in the beef merchandised at the retail level. Because the genetic base already exist for the cattle industry, we'll only need to incorporate the desirable production traits of various breeds with the desirable carcasses traits of other breeds and implement an excellent crossbreeding program which will incorporate the economic production traits with the production of lean, quality beef for the American consumer.

The concepts of strong on-the-farm testing programs are essential if the beef industry plans to be competitive with the poultry industry in the future. Even though we have a strong genetic base to reduce the fat and produce quality beef products for the American consumer, it is extremely critical that we continue to identify the most efficient and productive seedstock animals that will reduce the production cost and provide greater profits for all segments of the beef industry.

CONSUMER PREFERENCES

The beef industry developed an extremely strong market for high quality, but fat beef from 1950 through 1982. In 1982, beef consumption decreased and poultry consumption greatly increased (Table 1). With the major emphasis on low fat diets and other discriminatory comments about beef regarding human health and nutrition, a large number of consumers are purchasing less beef. This is particularly true of a select

group of high income consumers who have altered their eating habits and prefer light foods with low fat content (Yankelovich, et al., 1985). The surveys conducted by the National Livestock and Meat Board clearly show that the consumer prefers beef with considerably less marbling and less total fat than exists in the current U.S.D.A. Choice grade.

MARBLING VS PRODUCTION EFFICIENCY

The major factor responsible for high production cost for beef produced in the United States is directly related to the marbling requirement associated with the Choice grade. This has been an extremely controversial topic by all segments of the beef industry. It is difficult to understand this controversy because an objective review of the research reported on this topic clearly shows that marbling has limited influences on all palatability traits (Parrish, 1981). Meat scientists all know the limited influence of marbling on beef palatability. Scientists as well as industry leaders who want to promote the marbling concept find small differences that may exist in certain studies and use these data to support their views. If the industry is going to be competitive with other muscle foods in the future, these concepts will have to be removed from the leadership of the industry and we will have to produce beef with less subcutaneous, intermuscular, and intramuscular fat. It is very possible to produce beef carcasses with 73% muscle, .1 inches of fat at the 12th and 13th rib and still maintain excellent eating quality if the cattle are merchandised at a young age of 18 months or less. A comparison of the ideal carcass for 1968 versus the year 2000 (tables 3 and 4) indicates that the major differences is associated with the reduction of the three fat components of the beef carcasses.

Table 3. The Ideal Beef Carcass (1968)

Trait	Statistic
Carcass weight, pounds	600-650
Maturity	15 months
% Round, loin, rib, chuck	53 (Yield Grade 1)
% Edible portion	67
Loin eye area	14 square inches
Conformation score	Choice+ to Prime-
Fat thickness, 12th rib	0.3 inches
% Kidney fat	2.5
Marbling degree	Small to modest

From: D. M. Allen, 1968 Proc. Reciprocal Meat Conference.

Table 4. Desirable Beef Carcass (Year 2000)

Trait	Statistic
Carcass weight	700
Maturity	20 months
% Muscle	73
Loin eye area	15 square inches
Fat thickness	0.1 inches
% Kidney fat	1.0
Marbling score	Practically devoid

It is well established that extreme muscling deposition in beef carcasses along with a minimum amount of fat (.1 inches or less) can result in an abnormal condition often referred to as "double muscling". Cattle which possess double muscling traits have extreme reproduction problems and possess stress susceptibility traits that are undesirable in beef production systems. Fortunately, the beef cattle industry has a genetic base which can produce muscular and trim carcasses and prevent the development of double muscling characteristics. To guarantee that the introduction of the genes associated with double muscling are not increased, it will be necessary for the seedstock producers to develop a sound selection program which includes performance testing of economic traits associated with efficient production of quality, but low fat beef.

The existing production systems for beef cattle in the United States are extremely costly and require an intensive energy utilization for both production and processing. One method to reduce production cost for the beef industry is to reduce the fat content of the carcass and incorporate production systems which require less grain and more forage. Fortunately, production systems exist in the United States where maximum forage utilization can be used to produce beef cattle to a live weight of 900 to 1000 lb. These cattle can be placed in a feedlot and fed for sixty days on a high energy diet and be marketed in 18 months or less. Production systems of this type can greatly reduce the production cost and still provide a high quality rapidly acceptable beef product for the American consumer (Schmidt et al., 1985). Even though systems of this type exist today, they are often rejected by leaders of the industry because of the major economical investments in the existing, but traditional packing plants and feedlots which currently account for over 80% of the Good and Choice beef produced for the retail stores in this country. Unless the beef industry makes major changes in its production practices which will improve the efficiency, we will have a difficult time in competing with other muscle foods in the year 2000. Our greatest challenge in the beef industry may not be producing an ideal carcass with minimum fat, but produce a carcass that can be competitive with other muscle foods. We

have the technology for these systems, but we do not have an acceptable attitude of the existing beef cattle industry to incorporate the new technology which exist in reducing production costs for steaks and roasts merchandised at the retail stores. Because of the tradition and extremely large investment to produce the traditional steaks and roasts for the beef industry, it will be very difficult to make major changes in the beef industry before 1990. I believe from 1990 to the year 2000, the industry will be forced to make major changes in its production practices and processing techniques. Because existing technology already is available to make sweeping changes in the beef industry, it appears that stringent economical situations will have to exist before this technology is incorporated into our production and processing systems. I believe that by the year 2000, we will find a beef cattle industry more dependent on forage utilization and major changes will occur in the processing of beef to provide extremely lean but tasty beef products.

Literature Cited

- Allen, D. M. 1968. Description of ideal carcasses. Proc. Recip. Meat Conf. 21:284.
- Hendrickson, R. L. 1981. Energy aspects of prerigor meat. Proc. Recip. Meat Conf. 34:81.
- May, M. 1985. Personal Communication, USDA Meat Grading Service. Washington, D.C.
- Parrish, F. C. 1981. Relationship between beef carcass quality indicators and palatability. Proc. National Beef Grading Conference. Iowa State University, Ames, IA p. 46.
- Schmidt, S. P., T. B. Patterson, L. A. Smith, H. W. Grimes, J. L. Holliman. 1985. Postweaning performance of two management systems of calves out of Angus-Hereford and Simmental-Hereford cows bred to Angus and Polled Hereford bulls. J. Anim. Sci. 61 (Suppl. 1):426.
- Yankelovich, D., F. Skelly and A. White. 1985. Consumer climate for read meat: Executive Report. National Livestock and Meat Board, Chicago, Illinois.

FORAGE LEGUME BREEDING IN FLORIDA

David D. Baltensperger, G. M. Prine, K. H. Quesenberry

The University of Florida, Institute of Food and Agricultural Science (IFAS) has been involved with forage legume improvement for most of it's more than 100 year history. Currently there are more than 3 full time equivalents (FTE's) devoted to forage legume breeding. This includes partial research efforts of seven scientists working on more than a dozen genera of temperate, subtropical and tropical legumes.

Forage legume breeders are located at the IFAS, Agricultural Research and Education Center at Fort Pierce, Florida and at the main campus in Gainesville, Florida. Testing is conducted at these locations and at seven other research centers located throughout Florida.

TEMPERATE LEGUMES

Alfalfa (*Medicago sativa*) persistence and productivity in the humid southeast have been the primary goals of Dr. Earl Horner's program for more than 30 years. This program led to the development of 'FL 66', 'FL 77' and an improved population which is currently being evaluated for potential release. These cultivars and improved populations have consistently been the most persistent and productive in Florida. The current population has high levels of resistance to several root-knot nematode species and to the spotted alfalfa aphid.

White clover (*Trifolium repens*) breeding work was initiated by Dr. Horner more than 30 years ago also. The program has passed through the hands of several breeders in subsequent years, but the goal of improved persistence and productivity has stayed the same. This resulted in the release of 'Osceola' white clover and subsequent improved populations that are currently under regional evaluation for release. Short term goals of this program have shifted to improved nematode and virus resistance along with enhanced seed production potential.

Crimson clover (*T. incarnatum*) breeding work was initiated by Dr. G. M. Prine and continued under the direction of Dr. D. D. Baltensperger. Evaluation of numerous collections for immediate release and development of a broad based population for future

selection is now underway. Some of these collections are currently being evaluated in regional trials. It is anticipated that the most promising, FI-XPC-B, will be released in the coming year (Table 1). Current populations of early and late maturity are being screened for improved root-knot nematode resistance.

Table 1. Maturity of crimson clover, April 5, 1985.

Germplasm	Gainesville		
	Dairy	Campus	Jay
-----% flowering-----			
FL XPC B	100	100	95
Chief	20	10	5
Dixie	40	40	60
Tibbee	60	40	80

Subterranean clover (*T. subterraneum*) research has only recently advanced from the evaluation of plant introductions and Australian cultivars to the evaluation of naturally reseeding ecotypes for root-knot nematode resistance. Controlled crosses are now being made between resistant types and agronomically desirable types. Material from this program will not be ready for regional evaluation for at least three years.

Arrowleaf clover (*T. vesiculosum*) has been declining in productivity rapidly over the past five years in Florida. This decline has been associated with viruses, root-rots, and nematode buildup. The primary goal of the arrowleaf clover breeding program has been to identify and incorporate resistance to these pests, however, little positive variation has been identified to date. A major commitment and a little luck will be required to maintain the present acreage of this once popular legume.

Red clover (*T. pratense*) breeding was initiated by Dr. G. M. Prine and Dr. K.H. Quesenberry. Seed of three populations selected for (1) vigor, (2) early flowering, and (3) improved root-knot nematode tolerance are currently being increased for further regional testing. All populations have been shown to have higher root-knot nematode tolerance than more temperate germplasm. We expect that a new cultivar of this promising crop will be released within the next three years.

SUBTROPICAL AND TROPICAL LEGUMES

Aeschynomene (*Aeschynomene americana*) breeding research has been directed by Dr. K.H. Quesenberry for the past 7 years. Improved quality and less woody growth types, compared with the common type, have been selected. Grazing trials are

¹ Assistant Professor, Professor, and Associate Professor of Agronomy, respectively, IFAS, University of Florida, Gainesville, FL 32611.

currently being conducted on progenies that also carry nematode resistance. Additional grazing data will be collected prior to the release of the most promising of these. Studies on the inheritance of root-knot nematode resistance and photoperiod sensitivity are currently being conducted to provide an improved knowledge base for future breeding research.

Hairy indigo (Indigofera hirsuta) breeding research has been directed at improved seedling vigor and root-knot nematode resistance. A soft-seeded type with substantially larger seed has been identified. Crosses with the more agronomically desirable and disease resistant types are now being made.

Alyceclover (Alysicarpus vaginalis) utilization has been seriously hampered by susceptibility to root-knot nematodes and solving this problem has been the primary goal of the breeding program. Sources of resistance to each of three root-knot nematode species have been identified and crosses are currently being attempted to consolidate resistance to all three species in one line. Variation for seedling vigor, photoperiod sensitivity, forage quality and other traits has also been identified, however, no successful crosses have yet been achieved. Crossing technique development has subsequently become the highest priority. Lines with resistance to at least two of the nematodes are currently being evaluated for direct release.

Desmodium research has centered around the heterocarpon species and the closely related species, ovalifolium. Root-knot nematode resistance has been the primary breeding objective and sources of resistance have now been identified, especially high levels in D. ovalifolium (Table 2). The first successful crosses of D. heterocarpon x D. ovalifolium have been achieved and this gives encouragement to the long term goal of transferring the nematode resistance. Dr. A. E. Kretschmer, Jr. initiated Desmodium research more than 20 years ago and is still actively collecting germplasm around the world. Dr. Quesenberry is currently doing the breeding research.

Table 2. Gall scores of Desmodium spp. in response to infestation with Meloidogyne spp.

Desmodium Species	Meloidogyne Species		
	<u>arenaria</u>	<u>incognita</u>	<u>javanica</u>
<u>heterocarpon</u>			
FI-20	3.6	4.5	5.0
FI-143	3.9	4.4	5.0
FI-149	3.6	4.9	5.0
<u>ovalifolium</u>			
FI-28	2.4	0.2	3.1
FI-146	2.4	0.1	2.5
FI-147	2.4	0.0	3.3

Perennial peanuts (Arachis glabrata and other spp.) have been introduced and evaluated in Florida by Dr. A. E. Kretschmer, Jr. and G. M. Prine. This has led to the recent release of the nematode resistant cultivars 'Florigraze' and 'Arbrook'. Essentially no seeds are produced by these two cultivars. However, in the spring of 1986 several plants arising from seed were identified in a field that had been dug for rhizomes in the previous winter. These seedlings are now being evaluated for genetic variation and their potential to produce other seed.

Stylosanthes spp. breeding research has been directed by Dr. J.B. Brolmann for the past 15 years. Emphasis on cold hardiness, disease resistance, forage quality and most importantly, persistence, have led to the development of several lines which are currently being evaluated for cultivar release.

Dr. A. E. Kretschmer, Jr., C. G. Chambliss, and W. H. Pitman are currently evaluating collections of numerous other subtropical and tropical legumes for persistence and forage quality. Included in this work are the genera Vigna, Centrosema, Arachis, Desmanthus, Teramnus, Zornia, and others. Dr. G.M. Prine is doing similar work with subtropical and temperate species including Lotus, Vicia, Lespedeza, Cajanus, and others.

The continuation of these research efforts through the year 2,000 should lead to the development of a forage system with improved seasonal distribution of high quality forage for livestock production. Major advances can and must be made in the consistency of production of each of these forage legumes if they are going to play a part in fulfilling this long-term goal of all forage legume breeders.

GERMPLASM IMPROVEMENT IN THE MISSISSIPPI CLOVER BREEDING PROGRAM

W. E. Knight, M. M. Ellsbury, M. R. McLaughlin,^{1/}
G. A. Pederson, R. G. Pratt, and G. L. Windham^{1/}

The major emphasis of the Mississippi clover breeding program is on host-plant resistance to provide perennial and annual clover germplasm and/or cultivars with improved reliability and productivity through increased resistance to insects and diseases and to environmental stress. The major species in the program are arrowleaf clover, *Trifolium vesiculosum* Savi., berseem clover, *T. alexandrinum* L., crimson clover, *T. incarnatum* L.; subclover, *T. subterraneum* L. and white clover, *T. repens* L. This report will review recent releases from the program and the status of other germplasm under development.

RELEASED GERMPLASM

Bigbee Berseem Clover

'Bigbee', a winter-hardy berseem clover, was developed cooperatively by the USDA-ARS and the Mississippi Agricultural and Forestry Experiment Station (4,5). Bigbee is a selection for winter hardiness from the Italian cultivar Sacromonte. Selection was made during the growing seasons of 1970 to 1971 and 1971 to 1972. In January 1972, stands of Sacromonte were subjected to -15°C and -18°C within the same week. Seed was increased from surviving plants and evaluated in the Regional Annual Clover Variety Test from 1977 to 1983. Bigbee is the first cultivar of berseem clover to survive north of the Gulf Coast and Peninsular Florida. The level of winter hardiness in Bigbee gives it the same approximate range of adaptation as arrowleaf clover and crimson clover. Bigbee is susceptible to crown rot (caused by *Sclerotinia trifoliorum* Eriks.) root diseases, nematodes and bean yellow mosaic virus disease common to other forage legume species (1). To date, stands have not been lost from disease epiphytotics such as the virus-root rot complex which has destroyed stands of arrowleaf clover.

Bigbee was named and released in March 1984 by USDA-ARS and the Mississippi Agricultural and Forestry Experiment Station. Generations of seed increase are one generation each of breeder, foundation and certified. Breeder seed shall be maintained by the USDA-ARS at Mississippi State, MS. Foundation seed will be produced by

^{1/} USDA-ARS

Crop Science Research Laboratory
Forage Research Unit
Mississippi State, Mississippi 39762-5367

Foundation Seed Stocks, Mississippi Agric. and For. Exp. Stn., Mississippi State, MS 39762.

An exclusive release for market development and distribution was negotiated with Funk Seeds International. Adequate amounts of certified seed should be available in 1986 to meet the demand for this cultivar.

CHI-1 Crimson Clover

CHI-1 crimson clover germplasm was released by the Texas Agricultural Experiment Station, the Mississippi Agricultural and Forestry Experiment Station and USDA-ARS in December 1985 (17). CHI-1 is a simply inherited, non-strain specific, ineffective nodulation characteristic in crimson clover. A single plant of crimson clover with ineffective nodulation was selected under nil-N conditions from a 1000-plant population of 'Chief' (16). Ineffective nodulation is controlled by a single recessive gene pair (*rt₁*, *rt₁*) with possible modifiers. Plants with this trait should be useful as non-N₂ fixing controls in ¹⁵N isotope dilution experiments and to study individual steps in N₂ fixation. Seed may be requested from G. R. Smith, Clover Breeding Program, Texas Agricultural Research and Extension Center, Overton, TX 75684.

GERMPLASM PENDING RELEASE

Virus Resistant White Clover

A white clover germplasm with resistance to peanut stunt virus (PSV) was developed cooperatively by the South Carolina, Mississippi, North Carolina and Georgia Agricultural Experiment Stations and USDA-ARS. This germplasm was developed from 95 elite white clover clones from the white clover breeding programs at Clemson, North Carolina State and at VPI&SU, Blacksburg, VA. Of the 95 elite clones, 44 were identified as resistant to PSV after field testing in South Carolina, North Carolina, Mississippi and Georgia. A seed increase was made of the 44 clones in Washington. Six kg of seed was produced and will be available when the release is approved. Requests for seed should be directed to G. A. Pederson, Mississippi State, MS.

Drought Tolerant White Clover

Evaluation of drought-tolerant white clover clones has been completed (6,7). Synthetics made from polycross progenies of 22 clones selected for drought tolerance were evaluated for four years in white clover variety trials. Forage yield and persistence of the synthetics exceeded the 'Regal'

and 'Tillman' checks in the second, third, and fourth years of testing. Drought-tolerant synthetics had significantly less peanut stunt virus disease (PSV) than Regal and Tillman. Selection for PSV resistance apparently occurred concurrently with selection for drought tolerance. Preliminary results indicate tolerance to selected populations of the southern root-knot nematode is also present in this germplasm. A seed increase from the 22 clones has been made in preparation for a germplasm release. Seed will be available from G. A. Pederson, Mississippi State, MS when the release is approved.

Elite Crimson Clover Inbred Lines

Ten elite crimson clover inbred lines have been developed through recurrent selection. Criteria for selection were maintenance of vigor following inbreeding; adequate seed and forage production; and absence of disease symptoms. These elite lines were identified as superior following polycross testing in the field. Recently, these lines contributed to identification of root-knot nematode tolerance in the Florida clover breeding program (15). A seed increase is in progress prior to a germplasm release in 1986.

GERMPLASM UNDER DEVELOPMENT

Resistance to Fungal Diseases

The principal objectives of host-plant resistance research on fungal diseases are 1) identification of diseases that infect forage legume species; 2) determination of how these diseases limit productivity, stand longevity and survival; 3) evaluation of environmental conditions and their relationship to disease epiphytotics; and 4) development of disease resistant germplasm.

Four previously unidentified diseases of forage legumes have been identified and documented for the first time in the Southeast. These include Phytophthora root rots of arrowleaf and crimson clovers (11), a Fusarium wilt of crimson clover (12), a Cercospora leaf and stem disease of subterranean clover, and a noninfectious disease (internal crown breakdown) of arrowleaf clover. Phytophthora diseases of arrowleaf clover were shown to be more severe when plants were also infected by a common virus (3, 14). The life cycle of the Sclerotinia pathogen of crimson and other annual clovers has been clearly documented (13).

Research is in progress to evaluate effects of the Cercospora disease on seed production and seed quality of subterranean clover, and to evaluate management practices for control of the Sclerotinia disease of crimson clover.

Inbred lines of crimson clover with high levels of resistance to Fusarium wilt and moderate resistance to Phytophthora root rot have been developed (12). These will be combined in the future to provide new disease-resistant germplasm or cultivars. Screening for resistance to Phytophthora root rot of arrowleaf clover will be continued.

Resistance To The Clover Head Weevil in Crimson Clover

Resistance to the clover head weevil, Hypera meles Fab. has been identified in crimson clover inbred lines. Successful screening of clover for insect resistance is dependent on the capability for producing selection pressure through uniform infestation of candidate plant material. A reliable technique for ensuring a seasonal source of head weevils has been developed (2). The technique involves use of a motorcycle mounted collection net that collects weevils with efficiency about 10 times greater than hand held sweep nets. The system is capable of collecting overwintered adult weevils, later instar larval stage, and spring generation adults. The impact of the apparatus is significant since it allows collection of sufficient insects for host plant resistance studies during the very short (4 week) seasonal period during which these insects are available for study. The system has also proved valuable for collection of other clover pests and beneficial insects for scientific study.

Aphid Resistance in Crimson Clover

Selections have been made for aphid resistance in crimson clover. Open-pollinated populations were screened for resistance to Acyrthosiphon pisum Harris and Aphis craccivora Koch. Inbred lines with apparent resistance have been identified and increased. These lines will be retested to confirm resistance prior to a germplasm release.

Resistance to Root-Knot Nematodes

Studies have been initiated to determine the population dynamics and damage potential of root knot nematodes on annual and perennial clovers under field conditions. Screening of elite clover germplasms for resistance is in progress and will

be expanded to include both annual and perennial species. The pathogenic variation of root-knot nematodes on several white clover genotypes is being determined.

GERMPLASM ENHANCEMENT TECHNIQUES

Tissue Culture

Utilization of tissue culture techniques for crop improvement ultimately depends on successful plant regeneration. Many different culture conditions and media have been used to achieve plant regeneration in Trifolium species making efficient utilization of these procedures by other researchers difficult. Evaluation of four culture media for callus initiation and production of crimson, arrowleaf, white, and kura clovers, and development of procedures for plant regeneration via somatic embryo-genesis for the four Trifolium species has been completed (10).

For the first time, crimson clover plants have been regenerated from tissue culture via somatic embryogenesis. All regenerated plants to date are fertile with the normal chromosome number. Plantlets of arrowleaf clover have also been regenerated via somatic embryogenesis though none have survived to maturity. White clover and kura clover have formed proembryos although no germination has occurred. This study is the first step toward utilization of tissue culture technology in improvement of these clover species.

Screening for Resistance to Fescue Allelopathic Effects

A new technique was developed to test the allelopathic effects of tall fescue leaf extracts on white clover (9). White clover genotypes have been identified which show no reduction in germination or root growth and plants within species differ in their response to allelopathic compounds. This provides the basis for selecting white clover that can tolerate tall fescue allelopathy during initial stand establishment.

Hybridoma Biotechnology and Forage Legume Virus Identification

Hybridoma biotechnology is being used in cooperative forage legume virus research involving the Forage Research Unit of the Agricultural Research Service, U. S. Department of Agriculture, the Department of Plant Pathology and Weed Science,

and the College of Veterinary Medicine, Mississippi State University. Over 2300 hybridomas have been produced and tested in search of hybridoma cell lines which produce monoclonal antibodies useful in detection and identification of bean yellow mosaic virus (BYMV) and clover yellow vein virus (CYVV) (8). These viruses cause important diseases of clovers and other forage and food legume crops. The hybridomas were formed by fusion of mouse tumor cells, called myelomas, with antibody-producing spleen cells from mice immunized with purified virus. The hybrid cells carried the ability to grow and divide in culture (from the myeloma) and the ability to produce specific antibodies (from the spleen cell). The hybridomas were tested to identify those which secreted antibodies specific for BYMV and CYVV. Selected hybridomas were cloned to produce cultures derived from single cells. Antibodies secreted by single-cell clones are called monoclonal antibodies. Thirty-eight hybridoma clones were selected for monoclonal antibody production. Some of the monoclonal antibodies produced so far are specific to BYMV or CYVV while others react to varying degrees with both viruses. This suggests that while these viruses contain some antigenic determinants (epitopes) which are virus strain specific, they also share several common epitopes.

This technology offers several advantages over conventional antibody production methods which use serum obtained from the blood of immunized animals. Unlike antibodies obtained from immune serum, monoclonal antibodies from a single cell line are identical in reactivity and specificity, may be produced in laboratory tissue cultures rather than in live animals, and the hybridomas may be stored in liquid nitrogen for indefinite periods. Therefore, these hybridomas provide virtually inexhaustible and consistently uniform sources of antibodies for future research. By studying the reactions of BYMV and CYVV with a panel of several monoclonal antibodies, each with slightly different specificity and reactivity, the relationship between these viruses can be more precisely defined, providing basic information on virus structure and taxonomy, and improving disease detection and diagnosis capabilities.

SUMMARY

In the U. S., forage legumes have been criticized for being undependable and unreliable. Much of this is due to the minimal research effort devoted to the development of forage legume cultivars with resistance to major insect pests and diseases.

Maintaining a legume component in grazing systems may mean the difference in economic return to the producer. The margin of profit may result from a higher quality forage, stimulation of milk flow, higher calf weaning weights, and higher conception rates. In addition to these less obvious benefits, a well nodulated legume adds significant amounts of nitrogen for the grass component. Considerable progress has been made in the improvement of forage legume species in the past two decades. However, in order to provide forage legumes that are dependable and reliable, it is imperative that the germplasm development effort be accelerated to avoid excessive losses from an inevitable buildup of insect and disease pests.

Literature Cited

1. Baltensperger, D. D., K. H. Quesenberry, R. A. Dunn, and M. M. Abd-Elgawad. 1985. Root-knot interaction with berseem clover and other temperature forage legumes. *Crop Sci.* 25:848-851.
2. Ellsbury, M. M. and F. M. Davis. 1982. Front-mounted motorcycle net for mass collection of clover insects. *J. Econ. Entomol.* 75:251-253.
3. Ellsbury, M. M., R. G. Pratt, and W. E. Knight. 1985. Effects of single and combined infection of arrowleaf clover with bean yellow mosaic virus and a *Phytophthora* sp. on reproduction and colonization by pea aphids (Homoptera: aphidae). *Environ. Ent.* 14:356-359.
4. Kimbrough, E. L. and W. E. Knight. 1985. 'Bigbee' berseem clover MCES Info. Sheet. 2 pp.
5. Knight, W. E. 1985. Registration of Bigbee berseem clover. *Crop Sci.* 25: 571-572.
6. Knight, W. E. and M. R. McLaughlin. 1985. Apparent resistance to peanut stunt virus disease in white clover germplasm selected for drought tolerance. *Agron. Abstracts*, p. 60.
7. Knight, W. E., C. M. Rincker, M. R. McLaughlin, and N. C. Edwards. 1985. Evaluation of drought tolerant white clover germplasm. *Proc. So. Branch ASA*, Vol. 12: p. 2.
8. McLaughlin, M. R., S. W. Scott, and A. J. Ainsworth. 1986. Monoclonal antibodies to clover yellow vein and bean yellow mosaic viruses. *Phytopathology* (Abstracts in press).
9. Pederson, G. A. 1985. Allelopathic effects of tall fescue on germination and seedling growth of white clover genotypes. *Proc. XV Int. Grassland Congress* (In press).
10. Pederson, G. A. 1986. In vitro culture and somatic embryogenesis of four *Trifolium* species. *Plant Sci.* (In press).
11. Pratt, R. F. 1981. Morphology, pathogenicity, and host range on *Phytophthora megasperma*, *P. erythroseptica*, and *P. parasitica* from arrowleaf clover. *Phytopathology* 71:276-282.
12. Pratt, R. G. and W. E. Knight. 1986. Resistance to Fusarium wilt in selected inbred lines of crimson clover. *Crop Sci.* 26.
13. Pratt, R. G. and W. E. Knight. 1982. Formation of apothecia by sclerotia of *Sclerotinia trifoliorum* and infection of crimson clover in the field. *Plant Disease* 66: No. 11, pp. 1021-1023.
14. Pratt, R. G., M. M. Ellsbury, O. W. Barnett, and W. E. Knight. 1982. Interactions of bean yellow mosaic virus and an aphid vector with *Phytophthora* root diseases in arrowleaf clover. *Phytopathology* 72: 1189-1192.
15. Quesenberry, K. H., D. D. Baltensperger, and R. A. Dunn. 1986. Screening *Trifolium* spp. for response to *Meloidogyne* spp. *Crop Sci.* 26:61-64.
16. Smith, G. R. and W. E. Knight. 1984. Inheritance of ineffective nodulation in crimson clover. *Crop Sci.* 24:601-604.
17. Smith, G. R. and W. E. Knight. 1986. Registration of CHI-1 crimson clover germplasm. *Crop Sci.* 26.

BREEDING OF SERICEA LESPEDEZA (*Lespedeza cuneata* (DUMONT) G. DON.) IN ALABAMA. A HISTORICAL OUTLOOK.

Jorge A. Mosjidis¹

PALATABILITY AND TANNIN

Sericea lespedeza, a non-bloating legume, is one of the few summer perennial legumes well adapted to the large areas of marginal land found in the Southeast. It is used as a forage crop and in soil conservation.

Early work on this plant indicated it had low palatability and digestability (Clarke, Frey, and Hyland 1939). It was generally thought that the high content of tannins of sericea lespedeza was the cause of this problem. Not until 1953 did Wilkins, Bates, and Henson demonstrate that tannins had a definite effect on its palatability. In 1950, the Alabama Agricultural Experiment Station (AAES), Auburn University, initiated a breeding program to improve palatability and nutritive value of this crop. A free-choice grazing study with steers (Donnelly 1954) indicated that the most palatable sericea lines were those that had fine stems and a content of tannins less than 4%. Forty percent of the fine-stemmed and low-tannin plants were heavily grazed. Furthermore, 24 to 28% of the plants with fine stems and a content of tannins of 4.0 to 7.5% were heavily grazed. The stem effect is probably due to the fact that the xylem of the fine-stemmed plants is less lignified than that of plants with medium and coarse stems (Donnelly and Ferry 1957). Later, a feeding trial with rabbits confirmed that fine-stemmed sericea plants were more palatable than coarse-stemmed ones. It was also found that both types of stems had desirable and undesirable nutritive characteristics. (Donnelly and Hawkins 1959). Thus, the palatability problems of sericea plants were ascribed to stem fineness and tannins.

In 1962 the cultivar Serala was released (Donnelly 1965) by the AAES. A synthetic made up of six lines, has finer, more pliable stems, more stems per plant and does not become as coarse or woody as commonly grown strains of sericea. It has a high content of tannins. The yield of Serala was as good or better than the cultivars commonly used at the time (Donnelly 1963).

A mutation breeding program in cooperation with the University of Tennessee - Atomic Energy Commission Agricultural Research Program at Oak Ridge, Tenn., was started in 1957. A mutant was selected and released as a cultivar that could be used as a forage crop as well as on highway rights-of-way and in soil conservation areas. It

was named Interstate. The cultivar is short growing, uniform in height, profusely branched, fine stemmed, and with a high content of tannins. It also has good seedling vigor and produces more early herbage than Serala (Donnelly et al. 1970; Donnelly 1971).

Sources Of Variation of The Content of Tannins

Early work on the factors that affect the content of tannins of sericea plants had indicated that tannins did not remain constant as the season advanced (Clarke, Frey, and Hyland 1939; Stitt and Clarke 1941). Stitt (1943) found genetic differences in the content of tannins of sericea. But, he also suggested that the content of tannins was related to plant height, number of shoots, and yield. Later, Stitt, Hyland, and McKee (1946) found that height and seasonal weather conditions were not associated with changes in the content of tannins in the sericea plant. They also found that the amount of tannins was influenced by soil type and cuttings made on different dates on the same soil. Donnelly (1959) demonstrated that the content of tannins increased as the season advanced. He suggested that this increment was related to day temperature and rainfall because day temperature increased and precipitation decreased during the season. He also found that tannins did not decrease later in the season as reported by Clarke, Frey, and Hyland (1939) and Stitt and Clarke (1941). Donnelly's data also indicated that older tissue contains more tannins than younger tissue. Burns (1966) reported that a reduction in light intensity by shading plants lowered the content of tannins. But, shading the plants confounds temperature and light intensity effects, so Burn's results were inconclusive. Recently, Fales (1984) demonstrated that high temperature increases the content of tannins in sericea plants. Wilson (1955) reported that fertilizers and lime had no effect on the levels of tannins in sericea.

In short, from Still's (1943) and Donnelly's work (1954, 1959) it was clear that the main source of variation in the content of tannins of the sericea plant is the genotype. Temperature was found to have a secondary effect (Fales, 1984).

Effect of Tannins On The Forage Quality Of Sericea Lespedeza

Several studies were carried out to determine the relationship between tannins and various aspects of the forage quality of sericea lines with high or low tannins. It was found that sericea lespedeza leaves have more tannins than stems (Donnelly and Hawkins, 1959). Leaves of plants high in tannins have been found to have a digestable dry matter (DDM) only slightly higher than the stems of plants high in tannins. The DDM of stems low in tannins was as high as that of leaves high in tannins (Donnelly and Anthony 1973). It was also found that, on the average, lines with low content of tannins have more DDM, crude protein (CP), and digestable protein (DP) (Donnelly and Anthony, 1969, 1970; Donnelly,

¹Department of Agronomy and Soils, Auburn University, Alabama Agricultural Experiment Station, Auburn AL 36849

Anthony, and Langford, 1971). Thus, it was concluded that lines low in tannins have a higher nutritive value than lines high in tannins. Recently, Donnelly and Anthony (1983) reported results that indicate that tannins as well as other factors may affect digestible dry matter.

There are a few reports concerning the reasons for the poor quality of sericea forage induced by the presence of tannins. Smart et al. (1961) found that a water-soluble extract from sericea inhibited rumen cellulase. This result was confirmed by Lyford, Smart and Bell (1967). They also indicated that the inhibitory material extracted from sericea forage is responsible in part for the reduced digestibility of this forage crop. In 1963, Mandels and Reese suggested that plants use inhibitors of cellulase to protect themselves from invasion by fungi. Thus, it was reported that leucoanthocyanins (a kind of tannin) may inhibit fungal growth (Robinson 1975). These statements were prophetic with regard to the results of breeding aimed at reducing all types of tannins in sericea. Furthermore, Sarkar, Howarth, and Goplen (1976) reported that procyanidin (Rf 0.26 to 0.28) may be the type of tannin that is likely to be the cause of reduced digestibility and low palatability of sericea forage.

In short, tannins probably reduce the forage quality of sericea due to an inhibition of rumen cellulase. However, not all tannins are undesirable. Some tannins may provide the plants with protection to fungal disease. Hence, it would be more judicious to select more palatable plants by reducing or eliminating the undesirable tannins that seem to be associated with antinutritive properties, while retaining those with antibloating properties and those that protect plants from fungi attacks. We also need more information on the types of tannins present in sericea and their association with anti-nutritive properties. Furthermore, simple and inexpensive tests to identify the undesirable tannins would be needed in such a breeding program.

BREEDING FOR A SERICEA LOW IN TANNINS

In 1955, the sericea breeding program of the Alabama Agricultural Experiment Station, Auburn University, received the line low in tannins Beltsville 23-864, developed by AR-SEA-USDA. This line is also low in vigor, stemmy, light green in color, and generally undesirable (Donnelly and Anthony, 1980). The first crosses involving this line and lines high in tannins were made in 1959. Large nurseries of sericea lines low in tannins were planted. In 1969, a severe attack of Rhizoctonia sp. damaged the plants. From about 6,000 lines, 82 disease-free plants were selected. These plants were also low in tannins (Donnelly, 1983b). However, it was found that reaction of the lines to the disease is strongly influenced by the environment. Thus, rating of the plants for tolerance to Rhizoctonia in two consecutive years had a correlation coefficient of only 0.74. Also a high lines x

locations interaction has been reported (Donnelly 1983a,b). Thus, the breeding program for low tannins had an additional objective, namely, tolerance to Rhizoctonia. Out of this selection work came the sericea cultivar AU Lotan released in 1980 by AAES, Auburn University. AU Lotan contains an average of 50% less tannins than a normal sericea plant. At hay stage, digestible dry matter is 27% higher and crude protein is 7% higher than a cultivar high in tannins (Donnelly, 1981). However, the yield is lower than Serala. AU Lotan has had a yield that ranges between 58% and 98% of Serala with an average of 75% in seven environments (two years in two locations and three years in one location). It has a good resistance to Rhizoctonia sp. and to the root knot nematode Meloidogyne incognita acrita.

NEMATODE RESISTANCE

A second problem observed in sericea plants was that the stand of some lines thinned out or died out. It was found to be related to sensitivity to root knot nematodes (Donnelly and Minton 1968). Several lines of sericea were found to be highly resistant to Meloidogyne incognita incognita, M. incognita acrita, and M. hapla (Minton, Donnelly, and Shepherd, 1966). Resistance to M. hapla seems to be conferred by 1 or 2 dominant genes (Adamson et al. 1974).

In 1978, two cultivars, Serala 76 and Interstate 76, were released by the AAES, Auburn University the Georgia Agricultural Experiment Station and the AR-SEA-USDA. Serala 76 is a synthetic cultivar made up of 10 lines resistant to Meloidogyne incognita incognita and M. incognita acrita. Four of the 10 lines are also resistant to M. hapla. Serala 76 is a fine-stemmed, tall-growing cultivar similar to Serala in stem type and height (Donnelly and Minton, 1979).

Interstate 76 is made up of two lines. It is resistant to all three of the above mentioned species of root knot nematodes. Interstate 76 is a fine-stemmed, leafy, dense cultivar. It is intermediate between Serala and Interstate in height and has a more open growth habit than Interstate. It produces more early herbage than Serala or Serala 76 which makes it especially good for soil conservation. It is also a good forage producer. Both Serala 76 and Interstate 76 are high in tannins (Donnelly and Minton, 1979).

SEEDLING VIGOR

A third problem recognized in this crop was its slow germination and poor seedling establishment because the seedlings are weak and compete poorly with weeds. Logan, Hoveland, and Donnelly (1969) found an inhibitor of seed germination in the seed coat of sericea seeds. The germination experiments were carried out in petri dishes. No further work was done to relate the presence of this inhibitor to seed germination and seedling establishment under conditions where the inhibitor could be washed away. This line of work was not further pursued.

FUTURE PLANS

The problem of poor seedling vigor in sericea did not receive much attention in the past. Poor seedling vigor has a two-fold effect: (1) stand failure, and (2) poor growth during the year or establishment. As a consequence of the latter, plants are not usually cut or grazed during the first year to allow good establishment. Although the phenomenon of poor establishment in forage crops is well documented, few solutions to the problem have been proposed. Because of the many factors that can lead to poor establishment, more research is needed to understand the growth and development of sericea in order to carry out a successful breeding program on this matter.

Nevertheless, the few examples available of breeding programs that have succeeded in improving plant establishment (Townsend 1985), give enough guidelines to initiate a breeding program for seedling vigor in sericea that can be modified according to the results obtained on the experiments designed to understand this plant's growth.

Our first priority will be the screening and selection of sericea for greater dry matter production and faster early growth rates. Evidence that such a possibility exists comes from the report by Clements and Latter (1973). They succeeded in selecting Phalaris tuberosa for heavy seedlings.

Literature Cited

- Adamson, W.C., E.D. Donnelly, N.A. Minton and J.D. Miller. 1974. Inheritance of resistance to Meloidogyne hapla in Lespedeza cuneata. The Journal of Heredity 65:365-368.
- Burns, R.E. 1966. Tannin in sericea lespedeza. Ga. Agric. Exp. Stn. Bull. N.S. 164.
- Clarke, I.D., R.W. Frey, and H.C. Hyland. 1939. Seasonal variation in tannin content of lespedeza sericea. J. Agric Res. 58:131-139.
- Clements, R.J. and B. Latter. 1973. Responses to selection for seed weight and seedling vigor in Phalaris. Aust. J. Agric. Res. 25:33-44.
- Donnelly, E.D. 1954. Some factors that affect palatability in sericea lespedeza, L. cuneata. Agr. J. 46:96-97.
- Donnelly, E.D. 1959. The effect of season, plant maturity, and height on the tannin content of sericea lespedeza, L. cuneata. Agr. J. 51:71-73.
- Donnelly, E.D. 1963. Serala- A new sericea variety. Auburn Univ., Agr. Exp. Stn. leaflet 70 p. 1-4.
- Donnelly, E.D. 1965. Serala sericea. Crop Sci. 5:605.
- Donnelly, E.D. 1971. Registration of Interstate sericea lespedeza. Crop Sci. 11:601-602.
- Donnelly, E.D. 1981. Registration of AU Lotan sericea lespedeza. Crop Sci. 21:474
- Donnelly, E.D. 1983a. Breeding low-tannin sericea. I. Selecting for resistance to Rhizoctonia sp. Crop. Sci. 23:14-16.
- Donnelly, E.D. 1983b. Breeding low-tannin sericea. II. Effects of Rhizoctonia foliar blight on vigor and seed yields. Crop. Sci. 23:17-19.
- Donnelly, E.D. and W.B. Anthony. 1969. Relationship of tannin, dry matter digestibility and crude protein in sericea lespedeza. Crop Sci. 9:361-362.
- Donnelly, E.D. and W.B. Anthony. 1970. Effect of genotype and tannin on dry matter digestibility in sericea lespedeza. Crop Sci. 10:200-202.
- Donnelly, E.D. and W.B. Anthony. 1973. Relationship of sericea lespedeza leaf and stem tannin to forage quality. Agr. J. 65:993-994.
- Donnelly, E.D. and W.B. Anthony. 1980. New Auburn sericea variety 'AU Lotan', low tannin, nutritious forage. Auburn Univ., Agric. Exp. Stn. Highlights of Agric. Res. Vol. 27, No 2, Summer 1980.
- Donnelly, E.D. and W.B. Anthony. 1983. Breeding low-tannin sericea. III. Variation in forage quality factors among lines. Crop. Sci. 23:982-984.
- Donnelly, E.D., W.B. Anthony, and J.W. Langford. 1971. Relationships in low- and high-tannin sericea lespedeza under grazing. Agr. J. 63:749-751.
- Donnelly, E.D., R. Dickens, D.G. Sturkie, and J.D. Miller. 1970. Interstate sericea lespedeza. New variety for a special use. Auburn Univ., Agric. Exp. Stn. Highlights of Agric. Res. Vol. 17, No 2, Summer 1970.
- Donnelly, E.D. and J.F. Ferry. 1957. An analysis of the anatomy of three stem types of sericea lespedeza, L. cuneata. Proc. Assoc. Sou. Agri. Workers p. 59.
- Donnelly, E.D. and G.E. Hawkins. 1959. The effects of stem type on some feeding qualities of sericea lespedeza, L. cuneata, as indicated in a digestion trial with rabbits. Agr. J. 51:293-294.
- Donnelly, E.D. and N.A. Minton. 1968. Nematode-resistant sericea, now possible. Auburn Univ., Agric. Exp. Stn. Highlights of Agric. Res. Vol 15, No 2, Summer 1968.
- Donnelly, E.D. and N.A. Minton. 1979. Registration of Serala 76 and Interstate 76 sericea lespedeza. Crop Sci. 19:929.
- Fales, S.L. 1984. Influence of temperature on

chemical composition and in vitro dry matter disappearance of normal- and low-tannin sericea lespedeza. Can. J. Plant Sci. 64:637-642.

Logan, R.H., C.S. Hoveland, and E.D. Donnelly. 1969. A germination inhibitor in the seed coat of sericea (Lespedeza cuneata (Durmont) G. Don). Agr. J. 61:256:266.

Lyford, S.J., W.W. G. Smart, and T.A. Bell. 1967. Inhibition of rumen cellulose digestion by extracts of sericea lespedeza. J. of Animal Sci. 26:632-637.

Mandels, M. and E.T. Reese. 1963. Inhibition of cellulases and beta-glucosidases. In Reese, E.T. (ed). Advances in enzymic hydrolysis of cellulose and related materials. p. 115-157. Pergamon Press Inc., New York.

Minton, N. A. E.D. Donnelly and R.L. Shepherd. 1966. Reaction of varieties and breeding lines of sericea lespedeza to five root knot nematode species. Phytopathology 56:180-182.

Robinson, T. 1975. The organic constituents of higher plants. 3rd ed. Cordus Press. Mass. 347 p.

Sarkar, S.K., R.E. Howarth, and B.P. Goplen. 1976. Condensed tannins in herbaceous legumes. Crop. Sci. 16:543-546.

Smart, W.W.G., T.A. Bell, N.W. Stanley, and W.A. Cope. 1961. Inhibition of rumen cellulase by an extract from sericea forage. J. of Dairy Sci. 44:1945-1946.

Stitt, R.E. 1943. Variation in tannin content of clonal and open-pollinated lines of perennial lespedeza. J. Am. Soc. Agr. 35:944-954.

Stitt, R.E. and I.D. Clarke. 1941. The relation of tannin content of sericea lespedeza to season. J. Am. Soc. Agr. 33:739-742.

Stitt, R.E., H.L. Hyland, and R. McKee. 1946. Tannin and growth variation of a sericea lespedeza clone in relation to soil type. J. Amer. Soc. Agr. 38:1003-1009.

Townsend, C.E. 1985. Recurrent selection for improved seed germination, seedling elongation, and seedling emergence in cicer milkvetch. Crop Sci. 25:425-429.

Wilkins, H.L., R.P. Bates, and P.R. Henson. 1953. Tannins and palatability in sericea lespedeza, L. cuneata. Agr. J. 45:335-336.

Wilson, C. 1955. The effect of soil treatments on tannin content of lespedeza sericea. Agr. J. 47:83-86.

TREFOILS FOR THE SOUTHEAST

J. F. Pedersen¹ and C. S. Hoveland²

Birdsfoot trefoil (*Lotus corniculatus* L.), a native of Europe and parts of Asia, has been commonly grown in the central and northern United States for many years (Grant and Martin, 1985). It has not been regarded as being adapted in the Southeast. However, the recent releases of 'AU Dewey', GA-1, and 'Fergus' have extended the adaptation range into the upper portions of the Southeast.

The first southern trefoil cultivar, Fergus, was released in 1980 by the Kentucky Agricultural Experiment Station (Taylor and Templeton, 1985). Fergus was selected from a mixture of 'Empire' and a French introduction after 15 years of natural selection under grazing in Woodford County, Kentucky. It is the only one of the three cultivars with seed currently available commercially.

Both AU Dewey and GA-1 were released in 1985. AU Dewey was released by the Alabama Agricultural Experiment Station (Pedersen et al., 1986). It was developed from open pollinated seed of 13 plants selected from two Yugoslavian plant introductions. Selection criteria were rhizomatous nature, prostrate growth habit, and general vigor and adaptation in central Alabama.

GA-1 was released by the Georgia Agricultural Experiment Station as a germplasm (Fales et al. 1986). Although GA-1 was not released as a named cultivar per se, seed is already being increased in the northern United States. It was developed from crosses between a Brazilian introduction and 'Kimey', 'Granger', and 'Empire'. It arises from 15 clones selected from approximately 2000, after 7 years of natural selection at Experiment, Georgia.

The advantages and disadvantages of trefoil in the South were outlined by Hoveland et al. (1982). "Trefoil has several advantages: (1) tolerant of soil acidity, (2) drought tolerance, (3) not damaged by alfalfa weevil, (4) reseeds well from hard seed, (5) high quality forage, and (6) does not cause

bloat in cattle. Disadvantages are: (1) indeterminate flowering and seed shattering, generally resulting in low seed yields, and (2) susceptibility to crown and root-rotting diseases in the southern United States. In addition, northern trefoil varieties generally have poor seedling vigor and are slow to establish."

A forage species possessing all the above advantages is certainly needed in the South, especially if the above disadvantages can be rectified. Seed production problems in the South have been addressed by moving production northward to traditional trefoil-growing areas. Other problems with the species appear to have been overcome, at least in part, by the selection programs described.

Results of seed germination tests of several trefoil cultivars under stress conditions are shown (tables 1 and 2).

Table 1. Seed germination at two temperatures after 16 days.

Variety	Seed germination	
	68°F	86°F
	%	%
AU Dewey	90 a*	79 a
Fergus	92 a	73 ab
Viking	81 ab	63 bc
Dawn	79 ab	56 c
Empire	74 b	40 d

*Means within a column marked with the same letter are not significantly different at the .05 level of probability.

Table 2. Seed germination after 12 days as affected by simulated drought using a polyethylene glycol solution at 68°F.

Variety	Seed germination	
	0 bars	-3 bars
	%	%
Fergus	98 a*	98 a
AU Dewey	95 ab	85 ab
Viking	82 bc	75 bc
Dawn	82 bc	70 c
Empire	76 c	45 d

*Means within a column marked with the same letter are not significantly different at the .05 level of probability.

The improved germination of AU Dewey and GA-1 at high temperatures and under drought conditions common to the South is apparent, and should contribute to better stands and more effective reseeding.

¹Agronomy and Soils Department, Auburn University, AL 36849. ²Agronomy Department, University of Georgia, Athens, GA 30602.

Yield of these trefoils in monocultures and in grass mixtures has been very good without the use of nitrogen fertilizers (Hoveland and Fales, 1985). Trefoil yields and total yields of the mixtures are shown for a three year study conducted in northern Georgia (table 3).

Table 3. Yields of birdsfoot trefoil cultivars in monoculture and in association with grasses in the Piedmont area of Georgia, 3-year average.

Trefoil	Grass	Dry matter yield		Pasture	Grazing days/acre	Gain/acre	ADG
		Trefoil	Mixture				
-----lb./A-----							
AU Dewey	-	7607 a*	7607 a	TF ¹ + 150 lb. N	322 a	681 a	2.1
GA-1	-	6143 b	6143 b	TF + AU Dewey	228 b	550 b	2.4
Fergus	-	5750 c	5750 c	OG + AU Dewey	164 c	450 c	2.7
Dawn	-	5268 d	5268 d				
AU Dewey	TF ¹	3786 cd	6714 ab				
GA-1	TF	3295 de	6393 b				
Fergus	TF	2991 e	5527 c				
Dawn	TF	2071 f	5589 c				
AU Dewey	OG	4232 c	6527 ab				
GA-1	OG	4179 c	6063 b				
Fergus	OG	2839 e	5036 d				
Dawn	OG	3089 d	5036 d				

*Means within a column marked with the same letter are not significantly different at the .05 level of probability.

¹TF = 'Kentucky 31' tall fescue and OG = 'Hallmark' orchardgrass

In this test, AU Dewey and GA-1 clearly outperformed Fergus and 'Dawn', the northern check variety. High trefoil yields in grass mixtures show that this reseeding perennial legume may have a place in tall fescue (Festuca arundinacea Schreb.) and orchardgrass (Dactylis glomerata L.) pasture renovation.

As would be expected from the above, and from other grazing trials, cattle performance on southern trefoil/grass pastures is very good (table 4). Although total gain per acre was not as high as with nitrogen-fertilized tall fescue because of reduced grazing days, high average daily gains (ADG) with AU Dewey mixtures compensated for reduced pasture days (Hoveland et al. 1985).

Steer production on pure stands of GA-1 birdsfoot trefoil nearly equalled that on 'Apollo' alfalfa (Medicago sativa L.) in a three year study in central Georgia (Table 5). Although stocking rate was higher on the alfalfa, the longer grazing season (28 days) on the

Table 4. Steer performance on grass + nitrogen and grass + AU Dewey birdsfoot trefoil in North Alabama, 2-year average.

Pasture	Grazing days/acre	Gain/acre	ADG
no.	1b.	1b.	
TF ¹ + 150 lb. N	322 a	681 a	2.1
TF + AU Dewey	228 b	550 b	2.4
OG + AU Dewey	164 c	450 c	2.7

*Means within a column marked with the same letter are not significantly different at the .05 level of probability.

¹TF = Kentucky 31 tall fescue and OG = Hallmark orchardgrass

trefoil pastures compensated for fewer animals. The ADG's were high with both species. It should be pointed out that thinning of trefoil stands occurred at this location although natural reseeding was good. There is some question whether trefoils are adapted this far south when competition from warm season perennial growth can be severe.

Table 5. Steer performance on Apollo alfalfa and GA-1 birdsfoot trefoil in central Georgia, 3 year average.

	Alfalfa	Trefoil
Days grazing	105	133
Steers/acre	1.5	1.1
ADG, lb.	1.9	1.8
Gain/acre, lb.	283	243

During the first year of a grazing study in north Georgia comparing AU Triumph tall fescue + nitrogen fertilizer to AU Triumph + Fergus birdsfoot trefoil, results were similar to the Alabama study (Table 6). This study, however, also included an economic analysis of the treatments. The net return to land, labor, and management of the fescue + trefoil was double that of the fescue + nitrogen fertilizer.

After forage researchers complete their task of developing and testing new cultivars, one major question still remains. Will they work on the farm? Results of early demonstrations are encouraging. This response from an Alabama cattleman with demonstration plots of Fergus and AU Dewey supports our optimism. "If seed of trefoil was available, I would buy and plant more of it.....There are many different situations on different cattle farms and I believe that trefoil has a place on at least some of them."

Table 6. Steer performance and economic returns on AU Triumph + 120 lb. N/acre and AU Triumph + Fergus birdsfoot trefoil in north Georgia, 1985.

	AU Triumph +N	AU Triumph +Trefoil
Dates grazed	-- 3/12-8/1 --	
Steer days/acre	266	197
ADG, 1b.	1.7	2.1
Gain/acre, 1b.	457	435
Cost/acre, \$	58	33
Cost/lb. gain, \$	0.2	0.2
Net return, \$	44	89

Literature Cited

- Fales, S. L., D. G. Cummins, and R. E. Burns. 1986 Registration of Georgia 1 birdsfoot trefoil germplasm. Crop Sci. 26:205.
- Grant, W. F. and G. C. Martin. 1985. Birdsfoot Trefoil. p 98-117. In M. E. Heath, R. F. Barnes, and D. S. Metcalfe, eds. Forages-the Science of Grassland Agriculture 4th ed. Iowa State Univ. Press. Ames.
- Hoveland, C. S. and S. L. Fales. 1985. Mediterranean-germplasm trefoils in the southeastern USA Piedmont. Proc. XV International Grass. Congr. Kyoto, Japan.
- Hoveland, S. C., R. L. Haaland, R. R. Harris, and J. A. McGuire. 1982. Birdsfoot trefoil in Alabama. Ala. Agric. Exp. Stn. Bul. 537.
- Hoveland, C. S., R. R. Harris, R. L. Haaland, J. A. McGuire, W. B. Webster, and V. H. Calvert. 1985. Birdsfoot trefoil-grass pasture for steers in the Tennessee Valley. Ala. Agric. Exp. Stn. Bul. 567.
- Pedersen, J. F., R. L. Haaland, and C. S. Hoveland. 1986. Registration of AU Dewey birdsfoot trefoil. Crop Sci. 26: (in press)
- Taylor, T. H. and W. C. Templeton. 1985. Registration of Fergus birdsfoot treefoil. Crop Sci. 25:712.

A NEW LOOK AT ROSE CLOVER

G. R. Smith¹

INTRODUCTION

Rose clover (Trifolium hirtum All.) is a winter annual forage legume that produces a high percentage of persistent hard seed and is adapted to a broad soil pH range. Other attributes of rose clover include drought tolerance and very few pest problems identified to date. Limitations of current varieties of rose clover are: intolerance of poorly drained, wet soils; early maturity; and low productivity in the U.S. Southern Region. 'Kondinin' and 'Hykon', both developed in Western Australia, are the only certified rose clover varieties currently available. R. M. Love (1) has reviewed rose clover with emphasis on adaptation and production in California.

Reliable reseeding of annual clover is dependent on the interaction of climate, management, hard seed percentage and hard seed persistence (rate of softening) (2). Williams and Elliot (5) investigated the decline in hard seed percent of rose, subterranean (Trifolium subterraneum L.), and crimson (Trifolium incarnatum L.) clover under several environments in California. Averaged across five sites, four months after seed maturity, the hard seed percentage of 'Mt. Barker' sub, 'Common' crimson and 'Wilton' rose clover dropped to 8.4, 5.8 and 97.6%, respectively (5). The persistence of rose clover hard seed helps insure seed survival over seasons and years, thus increasing the reliability of this annual clover.

Objectives of the rose clover breeding program at Overton are: 1) identification of highly productive, full season (late maturing + good early growth) rose clover germplasm adapted to Texas; 2) maintenance of persistent hard seed and pest resistance traits in new germplasm.

MATERIALS AND METHODS

Initial Selection and Evaluation

Three hundred and eighty seedlings of rose clover were transplanted to a spaced-plant field nursery on November 15, 1982. 'Wilton' rose clover and plant introductions 287973, 311483, 287975 and 311485 were the germplasm base for this nursery. Soil pH was 6.8 (0-6 inches). Soil test ratings of phosphorus and potassium were low and very low, respectively. Prior to transplanting, 450 lbs/acre of 0-20-20 were applied to the Sawtown fine sandy loam soil. In early January 1983, plants showing winter freeze injury (23% of the nursery) were removed. In March and April, the remaining plants were rated for maturity and forage potential. Based on

these ratings, 19 rose clover lines were identified for further evaluation.

These 19 selections and their parental lines were planted at Overton in 3 ft rows on October 26, 1983. Seeding rate was 0.5 g/row of inoculated (Nitragin type WR with Pelgel) seed. Experimental design was a randomized complete block with two replications. Two evaluators rated these rose clover lines for stand, maturity and forage potential in March and April 1984. Ten superior lines were identified. At maturity, seed were harvested and a subsample was hand-cleaned for hard seed determination. Percent hard seed was measured by placing 200 seed from each line on moist germination paper in petri dishes (50 seed/dish, 4 dishes). The germination paper was checked daily and kept moist with deionized water. After ten days unimbibed seed were counted as hard seed.

Multi-Location Evaluations

Observation plots of the ten experimental rose clover lines and two check varieties, Kondinin and Hykon, were established in late October or early November 1984 at 8 Texas locations, including Overton, Dallas, Temple, College Station, Yoakum, Angleton, Beeville, and Weslaco. Nitragin inoculant (type WR) and six grams of seed per entry were provided which was sufficient to plant three replications of 12 ft rows at 15 lb seed/ac. Notes were taken at each location for winter damage, maturity, and forage potential. Seasonal forage production was measured at Overton.

RESULTS AND DISCUSSION

Initial Selection and Evaluation

Five hundred and twenty three annual clover plant introductions were evaluated at Overton in 1976-77 for stand establishment, seedling vigor and growth rate (4). From these original plant introductions rose clover was identified as one of several clovers with potential for improvement and use in Texas (3). This species is primarily self-pollinated but the percentage of outcrossing is enough (5%) for variation to occur within and among lines.

The final ten selections made from the 1984 seeded rows consisted of 3 lines from P.I. 287973, 4 lines from 311485, 2 lines from 311483 and one line from Wilton. In general, these 10 selections were rated better than the commercial varieties for vigor or forage potential and were later in maturity than Hykon or Kondinin (Table 1). The selections ranged from slightly earlier to slightly later than the variety Wilton. Hard seed percentage ranged from 81 to 54 percent for the selections and 88 to 82 percent for the commercial varieties. Further testing is in progress to determine the relative persistence of hard seed produced by the rose clover selections and commercial varieties.

¹/Assistant professor, Texas Agricultural Experiment Station, Overton.

Multi-Location Evaluations

Relative maturity and forage potential ratings for each location are shown in Tables 2 and 3. The frequency and date of notes varied between locations. To compare across locations, we have presented the notes taken around mid-April, where available. Forage potential of the experimental rose clover lines was rated higher at most locations than the commercial varieties, Hykon and Kondinin, which served as checks. The ratings were reversed at Beeville on notes taken March 27. This note was one to two weeks earlier than at other locations and many of the experimental lines were still in a vegetative growth stage.

All the experimental lines were later in maturity than Kondinin and Hykon. At Weslaco, many experimental lines were earlier than at the more northern locations. This was probably due to photoperiod response and higher temperatures. Late maturity in these experimental lines has resulted in a late April to mid-May bloom period at Overton. These lines are later in maturity than crimson clover, but earlier than arrowleaf (*Trifolium vesiculosum* Savi) clover. This trait should allow a good expression of yield potential but minimum competition with warm season perennial grasses.

Severe winter damage at Dallas resulted in complete stand loss of Kondinin and Hykon and 95% stand loss of line RR-12. Winter kill at Dallas of the remaining experimental lines ranged from 30 to 50%. Yoakum reported stand losses due to cold damage of 15, 13, and 7% for Hykon, RR-12, and Wilton, respectively. Rose clover line RR-12 appeared to be the least winter-hardy of the experimentals evaluated.

At Overton, rose clover production ranged from 2617 to 647 lbs DM/acre for M-13 and Hykon, respectively (Table 4). The highest yielding experimental rose clover (RM-13) produced 80 and 130% more forage than the checks Wilton and Kondinin, respectively. Genotype x environment interaction effects on forage production will be investigated in more detail next year.

With seed increases from the 1984-85 season, replicated forage production trials with these experimental rose clovers were established at Overton, Dallas, College Station, Angleton, Beeville, and Yoakum in the fall of 1985. Data from these experiments will provide more information concerning the future of rose clover in Texas.

Literature Cited

1. Love, R. M. 1985. Rose clover. In N. L. Taylor (ed.) *Clover Science and Technology*. Agronomy 25:536-545.
2. Salisbury, P. A., and G. M. Holloran. 1983. Inheritance of rate of breakdown of seed coat impermeability in subterranean clover. *Euphytica* 32:807-819.
3. Shipe, E. R., and F. M. Rouquette, Jr. 1980. Evaluation of 52 *Trifolium* plant introductions previously selected as having agronomic potential for East Texas. TAES, Dept. of Soil and Crop Sci., Dept. Tech. Rep. 80-6. p. 83-85.
4. Shipe, E. R., and F. M. Rouquette, Jr. 1980. Evaluation of 523 plant introductions of *Trifolium* spp. TAES, Dept. of Soil and Crop Sci., Dept. Tech. Rep. 80-6. p. 86-91.
5. Williams, W. A., and J. R. Elliot. 1960. Ecological significance of seed coat impermeability to moisture in crimson, subterranean and rose clovers in a mediterranean-type climate. *Ecology* 41:733-742.

TABLE 1. ROSE CLOVER SELECTIONS, PARENTAL LINES AND CHECKS FROM 1983-84 SEEDED ROWS

1983-84 Entry No.	1982-83 Nursery ID	Origin	April 26, 1984				
			Vigor ¹	Stand ² ---%---	Maturity ³	Height ⁴ inches	Hard Seed ⁵ ---%---
17	RH7	311483	4.1	99	2.7	8.5	81.0
18	RJ3	287973	4.4	98	3.0	10.5	59.5
21	RF20	287973	4.1	91	3.0	9.0	70.5
22	RO15	287973	4.8	96	3.0	11.5	76.7
23	RD3	311485	4.6	92	2.5	10.0	66.7
24	RD17	311485	4.3	97	3.0	9.5	68.7
26	RM13	311485	5.0	99	3.0	12.0	66.0
27	RM16	311485	4.4	96	2.7	10.5	66.0
13	RR12	Wilton	3.8	92	1.7	5.5	75.2
14	RH18	311483	3.7	81	2.0	7.5	54.5
1	-	Wilton	2.3	45	2.2	4.0	82.7
2	-	Ilykon	1.1	56	5.0+	4.5	88.0
3	-	Kondinin	1.4	67	5.0+	6.0	88.2
4	-	287973	4.0	96	2.7	9.0	75.0
5	-	311485	4.3	83	3.0	11.0	75.7
6	-	287975	3.7	89	3.7	8.0	76.5
7	-	311483	3.5	74	3.0	9.0	77.5

¹5 = vigorous, 1 leafy plant; 1 = stemy, low vigor plant (mean of two evaluators and two reps)²Mean of two evaluators and two reps³1 = vegetative, 5 = full bloom (mean of two reps)⁴Mean of two reps⁵Mean of 4 reps

TABLE 2. MATURITY RATING OF EXPERIMENTAL LINES AND COMMERCIAL VARIETIES OF ROSE CLOVER GROWN AT EIGHT TEXAS LOCATIONS IN 1984-85

Line	Overton	College Station	Beeville	Dallas	Yoakum	Temple	Angleton	Weslaco
RM-16	3.5 ¹	2.0	1.0	2.0	3.0	4.0	3.0	5.0
RR-12	3.0	2.6	4.0	1.0	3.0	--- ²	3.0	5.0
RH-18	3.0	2.0	4.0	2.0	3.0	--- ²	3.0	2.0
RH-7	4.0	2.6	1.0	2.0	4.0	3.0	3.0	5.0
RJ-3	3.5	2.6	4.0	2.0	4.0	3.0	3.0	4.0
RF-20	4.0	2.3	1.0	2.0	4.0	4.0	4.0	2.0
RD-15	3.5	2.3	1.0	2.0	4.0	4.0	3.0	2.0
RD-3	3.0	2.0	1.0	2.0	3.0	3.0	3.0	5.0
RD-17	3.5	2.6	1.0	5.0	4.0	4.0	3.0	5.0
RM-13	4.0	2.3	1.0	5.0	4.0	--- ²	3.0	4.0
Kondinin	5.0	4.3	4.5	--- ³	5.0	5.0	5.0	5.0
Ilykon	5.0	4.0	4.5	--- ³	5.0	5.0	5.0	5.0
Note Date	4-18	4-18	3-27	4-25	4-18	4-22	4-19	4-26

¹Maturity: 1 = vegetative, 2 = bud, 3 = late bud, 4 = first color, 5 = full bloom²Not included at this location³Winter-killed

TABLE 3. FORAGE POTENTIAL RATING OF EXPERIMENTAL LINES AND COMMERCIAL VARIETIES OF ROSE CLOVER GROWN AT SEVEN TEXAS LOCATIONS IN 1984-85

Line	Overton	College Station	Beeville	Dallas	Yoakum	Temple	Angleton
RM-16	4.9 ¹	4.0	2.0	3.0	4.3	3.8	4.0
RR-12	3.7	3.3	3.5	1.0	2.9	---	4.0
RH-18	4.9	4.0	2.5	3.0	3.7	---	4.0
RH-7	4.4	4.3	2.5	4.0	4.5	3.8	4.0
RJ-3	4.7	3.0	2.5	3.0	3.8	4.0	4.0
RF-20	4.9	4.0	2.5	3.0	4.3	3.3	5.0
RD-15	4.7	3.3	2.5	4.0	3.9	3.3	4.0
RD-3	4.8	4.3	2.0	4.0	4.5	3.5	4.0
RD-17	5.0	4.3	2.5	4.0	4.2	3.3	5.0
RM-13	4.7	3.3	2.5	5.0	4.0	---	5.0
Kondinin	2.9	1.3	4.0	---	3.1	2.5	2.0
Hykon	2.0	1.3	4.0	---	2.5	1.5	2.0
Note Date	4-18	4-18	3-27	4-25	4-18	4-2	4-19

¹Forage potential: 1 = poor, 5 = best

²Not included at this location

³Winter-killed

TABLE 4. FORAGE PRODUCTION OF ROSE CLOVER AT OVERTON, TEXAS, 1984-85

Variety ²	Harvest Date			Total
	3-26	4-16	5-14	
-----1bs DM/acre-----				
RM-13	824	1546	247	2617 a ¹
RF-20	704	1668	187	2559 a
RD-17	801	1383	214	2398 ab
RM-16	629	1510	163	2302 ab
RR-12	501	1388	309	2198 ab
RJ-3	534	1511	118	2163 ab
RO-15	531	1310	207	2048 abc
RH-18	495	1300	188	1983 abc
RH-7	398	1345	238	1981 abc
RD-3	465	1275	136	1876 abc
Wilton	292	953	215	1460 bcd
Kondinin	401	637	87	1125 cd
Hykon	299	315	33	647 d

C.V. = 19.6%

¹Yields followed by the same letter are not significantly different at the 0.01 level using the Student Newman-Keuls Multiple Range Test.

²Entries identified by letter-number combinations are experimental rose clover lines from the Overton clover breeding program.

THE BENEFITS OF FESCUE PASTURE RENEWAL

1
James E. Standaert

Tall Fescue is used extensively as pasture in beef cow-calf production in most Southeastern States. The discovery of a link between the existence of a fungus (*Acremonium Coenophialum*) in the tall fescue plant and poor animal performance by animals who consume the plant has led many producers to consider renewal programs for their fescue pastures. Such considerations require knowledge about 1) tested levels of fungus infestation in fescue pastures, 2) the costs of various renewal programs and 3) the stream of benefits forthcoming from various renewal options.

Fescue pasture renewal may involve merely seeding a legume into an infested stand, or it may involve totally destroying the stand and reseeding with fungus free seed with or without legumes. The establishment costs associated with the introduction of clover or total reseeding are well known and include charges for alternative feed sources for animals during renewal. Cost estimates for various pasture renewal options under North Carolina conditions are given elsewhere (Standaert, 1986). The remainder of this report will be taken up with estimating the benefits to be gained from renewal of fungus infested fescue pastures in a cow-calf production setting.

THE BENEFITS OF PASTURE RENEWAL

The benefit of pasture renewal is an avoidance of the animal symptoms associated with fescue fungus. With renewal cows will presumably yield more milk, calves will gain faster and breeding performance may be improved. For pastures with low levels of fungus infestation the benefits to renewal will be small and for those with high levels the benefits will be large. In this section, we attempt to attach specific monetary values to renewal of pastures with differing fungus infestation levels.

Since the discovery of the fungus has been so recent much about how it affects animals is still unknown. Scientists are now in the middle of experiments which examine how different levels of fungus affect level of milk production, level of calf gain, and level of breeding performance.

Another area in which information is lacking is the effects of different levels of fescue fungus infestation on animal consumption of the grass. Do animals experience poorer performance on grass with high levels of infestation because they eat less than they would grass with low levels of infestation? Or is the poorer performance due to poorer conversion of that which is consumed? Or both? These are important questions because their answers will help cow-calf operators

plan how their management (i.e. stocking rate, fertilizer amounts, hay storage) will change should they decide to renew their pastures. If most of the problem is a result of poor conversion of feed into beef gain (or milk) then lowering the fungus level by renewal will mean little change will be required in stocking rates if fertilizer amounts remain the same. If however, most of the problem is a result of an animals "going off feed", then animals consuming a renewed pasture will consume more at a faster pace than if the pasture remains in its infested state. It is likely that on renewed pastures stocking rates will be lower, or the grazing season will be shorter, or supplements to pasture will need to be supplied, or higher rates of fertilizer will need to be applied. In any case the the benefits to renewal must be adjusted by the costs these changes in management will impose.

In spite of the large amount we do not know about how the fungus affects feed consumption and performance by animals, cow-calf operators need to make informed choices about pasture renewal on what little evidence does exist. What follows is based on ad hoc guesses on the effect of fescue fungus on animal performance and consumption.

Effects of Fescue Fungus Renewal on Animal Performance:

Rule 1) For every 10 percent decline in infestation level, calf daily gains (ADG) increase by .1 lb/hd/day for the spring and summer grazing season.

Rule 2) For every 10 percent addition of clover to a grass sod, calf ADG increases by .1 lb/hd/day over the same season. The maximum clover in a clover-grass mix is 30 percent.

Effects Fescue Fungus Renewal on Animal Consumption:

Rule 3) Animals consuming fescue infested with fungus experience poor performance because they consume less.

Rule 4) For every .1 lb/hd/day increase in calf ADG, stocking rate (cow-calf units /acre) declines by 3 percent.

There have been numerous articles which contain calculations purporting to show the effect of Rule 1) on net returns to cow-calf production. A typical example is as follows: Renewing a pasture with 60 percent infestation to one with no infestation will lead to 120 more pounds of calf sold per acre if one cow-calf unit grazes one acre for 200 days. This additional output may be valued at current beef prices, say \$.60/lb, to yield an additional \$72 in net income per acre.

The problems with these calculations are two-fold. First, such calculations completely ignore the effect renewal will have on consumption of grass and hence soil nutrients. Net

1
Department of Economics and Business, N.C. State University, Raleigh. 27695-8109

income per acre must be adjusted downward by the value of the additional soil nutrients it takes to get an additional 120 pounds per acre. Second, the renewed pasture will produce a much heavier calf than will the unrenewed pasture. The heavier calf will command a lower per pound price than will the lighter calf. The \$.60 price used above needs to be adjusted by the weight discount experienced by the heavier calf.

In order to overcome these shortcomings in calculating benefits to fescue pasture renewal, the above rules were incorporated in model of a cow-calf enterprise grazing fescue over a 216 day season. Per acre gross revenues and "fungus savings" were calculated for two reestablishment options, one with clover and one without, and a renovation option, for alternative levels of initial fungus infestation. "Fungus savings" are essentially increases in net return per acre due to renewal. Given initial investment costs for each renewal option, a rate of return was calculated at each infestation level. For those treatments with clover (assumed to live three years), yearly credits for nitrogen savings and triennial debits for clover renovation were added to the cash flow generated by fungus savings. Table 1 gives yearly and triennial maintenance cost comparisons for a clover-fescue stand versus straight fescue stand.

The basic model is that given in the NRC, Nutrient Requirements for Beef Cattle. Additional assumptions are:

1. The dry matter available for consumption per acre per grazing season is constant across all infestation levels and forage species.
2. Total consumption per acre per grazing season by the herd is constant across all infestation levels and forage species.

These obviously false assumptions imply that it is possible to infinitely vary stocking rate. The purpose behind their use is to attempt to control for differences in management between a situation in which an infested acre is fully stocked (i.e. all available dry matter is consumed) and one in which a fungus free acre is fully stocked. The bias against renewal these assumptions may engender is readily admitted.

While feed demand can be fairly easily characterized, pasture feed supply available to satisfy such demand cannot. Here we make the initial assumption that there are 5000 pounds of dry matter (at NRC values for NEm and NEg) available for consumption and that all of it is consumed. This value is varied in the sensitivity analysis below. The supply of forage available under different fungus infestation levels and forage species types has always offered a great problem in measurement. Without more research to tell us how availability will vary in these situations, we let the above assumption suffice.

RESULTS

Table 2 gives gross revenue per acre, stocking

rates, calf sale weights, prices, fungus savings and rate return for three renewal options given an initial infestation level. Various assumptions concerning calf beginning weights, calving percentage, grazing season length, etc. are given in the footnotes to that table. See Standaert, 1986 for a more detailed version of model input assumptions.

In Table 2, note that gross income generated by each acre is similar regardless of infestation level. This is because as infestation levels decrease, increases in calf sale weight per cow are offset by reductions in the number of cow-calf units each acre will carry, as well as reductions in the value of each pound of calf produced. As infestation levels decrease the proportion of gross revenues generated by the offspring of the cow increases while the proportion generated by the cow decreases. Now each cow-calf unit an acre is not required to carry represents a savings in per head costs (vet & med, labor & mgmt, interest and other). Therefore, net returns per acre increase as fungus infestation levels decrease.

Table 2 presents these increases in net returns, labelled there as fungus savings, for each renewal option. In the body of the table these savings are given as the upper number under each option. The lower number is an internal rate of return computation. The internal rate of return is computed assuming an initial investment in year 1 (as given in the first line of Table 2), and a stream of cash inflows and outflows in 21 subsequent years of grass stand life. For the grass reestablishment treatment, only fungus savings make up subsequent year cash inflows. For the two clover treatments, maintenance and triennial cost differences are added to fungus savings in each year.

Negative infestation levels correspond to addition of clover to low fungus or zero fungus pastures.

The rate of return in Table 2 is a real rate. That is, all cash flows are after inflation has been accounted for. A minimum real rate of return would probably be in the 3 to 4 percent range for investments of the length of term we are considering here. If we use 3 percent as a minimum, Table 2 shows that renovation of a pure grass stand by seeding clover into it will always meet that criterion regardless of infestation level. This does not mean that this option will always dominate the other two options. Table 2 shows that if sample infestation levels exceed 40 percent, total reestablishment with a clover grass stand will dominate. It also shows that reestablishment with a clean straight fescue stand will never dominate, but will come close to the clover-grass reestablishment option at high rates of infestation.

Of course, if required minimum real rates of return are higher, investing elsewhere may be wiser than pasture renewal if infestation levels are low.

Table 1. Maintenance year costs for fescue and fescue clover pastures

Category	Fescue					Fescue/Clover				
	Units	Price	Quantity	\$/ac	Category	Units	Price	Quantity	\$/ac	
Operating Inputs										
0-10-20, bulk 30% Nitrogen	cwt. cwt.	7.35 6.25	4.00 5.00	\$29.40 31.25	0-10-20, bulk	cwt.	7.35	5.00	\$36.75	
Tractor fuel & lube				4.00	Tractor fuel & lube				2.00	
Tractor repair				1.50	Tractor repair				.75	
Machinery repair				.90	Machinery repair				.45	
Total yearly operating cost				67.05	Total yearly operating cost				39.95	
Lime, applied every three years	ton	31.00	1.00	31.00	Lime applied every three years	ton	31.00	2.00	62.00	
					Renovation every three years (exclusive of lime)				71.94	
Total triennial maintenance cost				98.05	Total triennial maintenance cost				133.94	

Table 2. Savings from fescue pasture renewal, by fungus infestation level. Also stocking rates and internal rates of return over 21 year life of stand.

Infestation Level(a)	Ending Grazing Weights(c)	Price	Stocking Rate (Cow- Calf Units)	Gross Returns per Acre	Fungus Savings		
					Internal Rate of Return		
					Reestablishment Clover/grass(d)	Renovate Grass	Renovate Clover/grass
%	lbs	\$/cwt	CC/acre	\$/acre	\$/ac %	\$/ac %	\$/ac %
Initial Investment					\$175	\$140	\$143
Maintenance Year Expenses					\$40	\$67	\$40
Triennial Year Expenses					\$134	\$98	\$134
-30	steer	654	63				
	heifer	590	55				
	cow	1000	35	.80	257	---	---
	repl.(b)	910	53				
-20	steer	632	63				
	heifer	567	55				
	cow	1000	35	.83	259	---	---
	repl.	889	53				
-10	steer	610	63				
	heifer	547	55				
	cow	1000	35	.86	260	---	---
	repl.	867	53				
0	steer	589	65				
	heifer	526	55				
	cow	1000	35	.88	266	1.64 1.1	---
	repl.	824	53				1.64 3.2
10	steer	567	65				
	heifer	504	55				
	cow	1000	35	.91	267	4.21 3.6	2.57 -8.1
	repl.	824	53				2.52 4.2

Table 2. Savings from fescue pasture renewal (continued).

	steer	546	65					
	heifer	482	56					
20	cow	1000	35	.94	268	<u>6.37</u> 5.5	<u>4.74</u> -3.5	<u>3.20</u> 6.0
	repl.	802	53					
	steer	524	65					
	heifer	461	56					
30	cow	1000	35	.97	269	<u>9.64</u> 8.2	<u>8.01</u> 1.3	<u>8.01</u> 9.9
	repl.	781	53					
	steer	502	65					
	heifer	439	56					
40	cow	1000	35	1.00	269	<u>13.10</u> 11.0	<u>11.66</u> 5.4	<u>9.09</u> 10.9
	repl.	759	53					
	steer	481	67					
	heifer	418	56					
50	cow	1000	35	1.04	273	<u>13.26</u> 11.0	<u>11.63</u> 5.4	<u>6.89</u> 8.8
	repl.	738	53					
	steer	459	67					
	heifer	396	57					
60	cow	1000	35	1.07	273	<u>17.11</u> 13.9	<u>15.48</u> 9.1	<u>7.47</u> 9.3
	repl.	716	53					
	steer	438	67					
	heifer	374	57					
70	cow	1000	35	1.11	273	<u>22.14</u> 17.4	<u>20.50</u> 13.5	<u>8.84</u> 10.7
	repl.	694	54					
	steer	416	67					
	heifer	331	57					
80	cow	1000	35	1.14	271	<u>27.65</u> 21.1	<u>26.01</u> 17.9	<u>14.39</u> 15.7
	repl.	673	54					
	steer	394	69					
	heifer	331	57					
90	cow	1000	35	1.18	274	<u>29.88</u> 22.5	<u>28.24</u> 19.6	<u>12.77</u> 14.3
	repl.	651	54					
	steer	373	69					
	heifer	310	57					
100	cow	1000	35	1.22	272	<u>36.56</u> 26.9	<u>34.92</u> 24.6	<u>14.42</u> 15.7
	repl.	630	54					

- (a) Negative infestation levels represent the addition of clover to a fescue pasture.
- (b) The culling rate for replacement heifers is 50 percent higher than for cows. All cows not producing calf for sale are sold.
- (c) For this example, calving percent is 82, per cow costs are \$123. Calves are born December- January and sold in November. Grazing season is 216 days; available dry matter per acre is 5000 pounds. Clover stand life is three years; fescue stand life (infested or not) is 21 years. IRR is computed over a 21 year period. Initial weights and rates of gain at zero infestation are: Steers(200,1.6), Heifers(180, 1.4), Cows(1000, 0), Replacement heifers(500, 1.4) in pounds and pounds per day.
- (d) Fungus savings for clover/grass assume a 30 percent clover-70 percent grass mixture. Fungus savings listed do not account for difference in maintenance and triennial year costs. However, IRR does.

Table 3. Sensitivity Analysis: effects of changes in model assumptions on domination range of fescue pasture renewal options.

Variable changed	Reestablishment Clover/Grass	Grass	Renovation Clover/Grass	Invest Elsewhere (Return 3 %)
Domination Range, Percent				
Baseline solution	40 - 100	---	0 - 40	---
Pasture Variables				
Clover, 2 yr. life	40 - 70	70 - 100	30 - 40	0 - 30
Grass life, 15 years	60 - 100	---	0 - 60	---
Available dry matter (5000+10*i)	---	---	80 - 100	0 - 80
Animal Performance Variables				
Calving percent, -10 %	---	---	30 - 100	0 - 30
Calving %, (.82-.0005*i)	30 - 100	---	0 - 30	---
Gain rule, -20 %	40 - 100	---	20 - 40	0 - 20
Cow gain, (-.005*i)	60 - 100	---	30 - 60	0 - 30
Financial Variables				
Price discount for weight = 0	20 - 100	---	0 - 20	---
Price discount for weight, dbld.	60 - 100	---	30 - 60	0 - 30
Zero fixed costs	---	---	80 - 100	0 - 80
Maint. cost difference, -20%	40 - 100	---	30 - 40	0 - 30
Triennial cost diff., +20%	40 - 100	---	20 - 40	0 - 20
M & T cost difference = 0	---	40 - 100	---	0 - 40

SENSITIVITY ANALYSIS

In this section, some of the model variables whose values are least known will be varied to test the sensitivity of rates of return. Table 3 gives the results of this analysis. In addition to the three renewal options a fourth option is included. This is to invest elsewhere and earn a return of at least 3 percent in real (inflation adjusted) terms. The numbers in Table 3 give the range in which a particular option dominates all other options when the indicated variable is altered. Only one variable is altered at a time. The first line of the table gives the baseline solution.

Pasture Variables

Clover life. Because of weather, slope, acidity levels, etc., clover may not last the three years assumed in the baseline solution. Assuming a two year clover life substantially changes cash flows associated with clover maintenance and renova-

tion. In the baseline solution, renewal with a three-year clover crop paid for triennial renovation costs with three years of nitrogen savings. With a two-year clover crop, renovation costs are incurred more frequently and only two years of nitrogen savings are available to pay for renovation. With a two-year clover crop it would take infestation levels of at least 30 percent before renewal becomes preferable to investments in other projects earning at least 3 percent. At levels of infestation greater than 70 percent, the straight grass reestablishment option is the most preferable.

Grass Life. On the other hand suppose that fungus free grass does not have the longevity of infested grass. Suppose fescue with any positive level of infestation lasts 21 years as in the baseline solution, but that zero infested fescue has a life of only 15 years. This does not affect the rate of return to the renovation option but does affect the rate of return to each reestablishment option. As a result the renovation option is dominant up to the 60 percent infestation level.

Available Dry Matter. Allowing dry matter availability to increase as I level increases causes stocking rates to dramatically increase. Gross revenue per acre rises faster than do per cow costs as I level increases. Renovation is the dominant option for I levels above 80 percent. Investing elsewhere dominates for lower levels.

Animal Performance Variables

Calving Percent. A reduction in calving percent raises feed requirements per cow-calf unit because of the extra replacement heifers the unit must carry. Lower calving percent thus means lower stocking rates at each level of infestation. As infestation levels increase, the pounds of calf sold per acre are nearly constant, but the pounds of cow and replacement heifer sold per acre increase. Thus gross revenue per acre increases with higher I levels and increase at a rate similar to increases in per cow costs. The result is that renovation is the only renewal option which dominates, but does so only for infestation levels above 30 percent.

When calving percent is allowed to vary negatively with infestation level, the dominating options are very close to those in the baseline solution.

Gain Rule. The gain rule was decreased by 20 percent so that each 10 percent improvement in fungus infestation level was associated with a .08 pound per day difference in calf gain. This of course reduces some of the benefits to pasture renewal. The result is that the "invest elsewhere" option dominates for I levels below 20 percent, the renovation option for levels between 20 and 40 percent and the clover-grass reestablishment option dominates for levels above 40 percent.

Financial Variables

Price Discounts. Allowing no price discounts for heavier weighted calves increases the range over which the clover-grass reestablishment option dominates. Similarly doubling the discount for added weight causes the invest elsewhere option to dominate for I levels up to 30 percent. The renovation option dominates for I levels between 30 and 60 percent and the clover-grass reestablishment option dominates for all higher levels.

Zero Fixed Costs. Fixed costs are interest and depreciation on value tied up in every cow-calf unit. If these costs are set at zero, most of the per cow cost savings associated with lower stocking rates are erased. It makes little sense to engage in any renewal option under these conditions unless infestation levels are very high.

Maintenance Cost Difference. Reducing the cost difference between maintaining fescue-clover and straight fescue by twenty percent shifts much of the advantage that renovation enjoyed in the baseline solution to the invest elsewhere option. This reflects the fact that at low levels of infestation renovation is the dominant option not because of fungus savings but rather because

of savings in maintenance costs.

Triennial Cost Difference. When both maintenance and triennial cost differences are set equal to zero, three-year clover in any renewal option loses its dominance at all levels of infestation. The reestablishment of straight fescue dominates for I levels above 40 percent.

FUTURE RESEARCH

Research needs concerning the effects of fescue fungus on animal performance and consumption are many. First, we must try and learn how it is that the ingestion of the fungus affects the animal. Is it a toxic effect which reduces the rate at which the animal is able to convert feed into product or is it an appetite depressant? How does the fungus affect ability to rebreed, fetal growth and abortion incidence? Do different breeds of animal respond differently to the presence of the fungus in fescue material?

Second, how long will fungus-free fescue live under different management regimes; will fertilizer response be the same for fungus-free grass as it is for infested grass; what is the longevity of the plant if attacked by insects; and finally what is gain response difference under pasture neglect?

Third, how should management practices be altered in a fungus-free situation; should fertilizer amounts be increased; what stocking rates should be recommended?

Finally it appears that farmers are slow to adopt the new fungus free varieties. Why? A large part of the savings to be gained from replacement of the older varieties is the reduction in per head costs each renewed acre enjoys. Beef cattle producers are notoriously slow in responding to changes in these costs. What educational effort needs to be brought to bear in order to speed up the process of adoption of the newer more productive varieties?

Literature Cited

Green, J., J. P. Mueller, W. M. Lewis, J. E. Standaert. "Tall Fescue Endophyte: Forage Crop Newsletter, Memo No. 16, Feb. 1985. N. C. Agricultural Extension Service. NCSU.

Jacobs, V. E. "The Subtle Economics of Improving Pasture Quality in Summer Grazing Programs." Farm Management Newsletter, May 28, 1983 Missouri Cooperative Extension Service.

National Research Council. Nutrient Requirements for Beef Cattle. 6th revised edition, 1984.

Standaert, J. E. "The Cost and Benefits of Fescue Pasture Renewal." Economic Information Report, Department of Economics and Business, NCSU Forthcoming.

PROGRESS OF S-167 REGIONAL PROJECT

C. P. Bagley¹

The S-167 Regional Project entitled "Utilization of Forages for Production of Slaughter Cattle Throughout the Year" was initiated in 1981 and scheduled for termination in September, 1986. The project has as its objectives to 1) develop and evaluate forage and cattle management systems to enhance efficiency of resource utilization for uniform distribution of slaughter cattle production throughout the year, and 2) estimate the economic feasibility of year-round production of slaughter cattle under different physiographic conditions.

Under the main objectives were five study areas which included a) calf production, b) growing-finishing production systems, c) legume-grasses, d) forage production and utilization, and e) economic analysis of production systems.

State experiment stations which were cooperators in this study included Arkansas, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Puerto Rico, South Carolina, Texas and Virginia, along with the USDA-ARS location in Oklahoma. The participants have met on an annual basis to discuss research results and discuss further directions. The S-167 group has maintained close contact with the S-156 (Southern Region Project "Simulation of Forage and Beef Production in the Southern Region") group and have had joint annual meetings on two occasions.

One of the more important aspects of the S-167 group has been its recommendations on data collection procedures for forage-beef grazing studies. The list of data to be taken was derived from scientists' input from several disciplines. While the committee responsible for the recommended procedures does recognize that these can not be followed in all studies, these procedures will yield more in-depth details which would be useful in adapting these studies to the modeling efforts currently underway.

A large volume of data has been published in numerous publications. This regional project has provided for enhanced communication between scientists between states and has led to a more concentrated effort in several research areas. Presently, a final report on the project is being developed with the project to be terminated September, 1986. Currently, a regional project is being proposed which will not be a continuation of S-167, but it will use data and knowledge generated from both S-156 and S-167 to glean the strongest points of both studies along with some more recently recognized high-priority research areas.

¹/ Rosepine Research Station, La. Agr. Exp. Sta., LSU Agricultural Center, P. O. Box 26, Rosepine LA 70659

YIELD AND QUALITY DIFFERENCES AMONG CULTIVARS
OF ENDOPHYTE-FREE TALL FESCUE

Joe Bouton¹

Of the many tall fescue (*Festuca arundinacea* Schreb.) cultivars available, the following are reported by forage extension specialists to be currently used or recommended in the Southeastern United States (J. H. Bouton, unpublished survey): Forager, Johnstone, Kenhy, Kentucky 31, Missouri 96, and AU Triumph. However, when year of release of each cultivar is examined (Buckner, et al., 1985; Balauch, et al., 1980), then it is noticed that Kentucky 31 was released in 1943 and the other cultivars were released between 1977 and 1982. Why is there a 34 year gap between Kentucky 31 and the others? I think the answer lies simply with the endophyte fungus (*Acremonium coenophialum* Morgan-Jones and Gams) which infects tall fescue. By not knowing the level of fungal infestation (or even for that matter that the fungus even existed), testing cultivars against Kentucky 31 during this 34 year period would and did give contradictory results. It wasn't until recently when endophyte-free versions of cultivars were available could agronomic or animal performance differences be assessed.

Differences in total seasonal yield are a very traditional means of assessing cultivar performance. The data presented in table 1 show results from recent cultivar trials. Three important points can be made from these data. First, there is a great deal of variation from state to state for cultivar performance. This indicates each cultivar's adaptation and performance needs to be assessed before recommendation. Each state should not rely too strongly on results from neighboring states. Second, total yield can be misleading if one needs a certain seasonal distribution of the yield. An example is the cultivar AU Triumph whose superiority in autumn and winter production was shown at all the testing locations in table 1. Production during this period would have great potential for certain grazing systems. Third, there was no indication from any of the trials about the fungal endophyte level for each cultivar. This could be important if future experiments prove endophyte infestation leads to more (or less) yield and persistence. To avoid this problem, future yield trials should be conducted with fungus free swards of each cultivar since that is how the farmer will use them.

Of utmost importance to many would be the differences among tall fescue cultivars in terms of animal performance. Because the fungus problem has so recently been demonstrated, there are few data on cultivar differences for animal gains. The data summarized in table 2 show the new cultivars Johnstone and AU

Triumph to give superior animal performance when tested against Kentucky 31 comparably infected with a low level of fungus. Therefore, it appears from these limited data that at least when grown in their areas of adaptation, the newer cultivars give better animal performance when compared to the old standard Kentucky 31.

In summary, the fungus problem greatly limited past assessment of animal performance differences among tall fescue cultivars. Recent data on the newly released cultivars have shown their superiority to Kentucky 31 when tested in fungus-free swards. However, future assessments of new cultivars against standards such as Kentucky 31, will need to be conducted at low fungus infestation levels and determined on a state by state basis before true differences can be demonstrated among cultivars.

Table 1. Relative annual yield of tall fescue cultivars at different locations in the Southeastern United States.

Cultivar	Alabama [†]	Georgia [‡]	North Carolina [§]	Tennessee [¶]
	(%)			
Kentucky				
31	100	100	100	100
Forager	---	96	109	94
Kenhy	89	100	94	97
Missouri				
96	80	104	83	103
AU Triumph	111	113	97	100

[†]From Pedersen, et al., 1982.

[‡]From Wilkinson, et al., 1984.

[§]From Daniel, et al., 1983 and Daniel, et al. 1985.

[¶]From Reynolds, 1984.

Table 2. Relative animal performance in terms⁻¹ of average daily gain (ADG) and total gain ha⁻¹ of 3 tall fescue cultivars containing low fungal endophyte levels when tested in three states.

Cultivar	Alabama [†]		Georgia [‡]		Kentucky [§]
	ADG	Gain ha ⁻¹	ADG	Gain ha ⁻¹	ADG
Kentucky					
31	100	100	100	100	100
Johnstone	---	---	121	110	127
AU Triumph	123	117	127	149	---

[†]Grazing period Oct. - Dec., 1980-83; from Pedersen, et al., 1986.

[‡]Grazing period April - Nov., 1984-85; from John Stuedemann, unpublished data.

[§]Grazing period 112 days, Spring-Summer, 1983; from Buckner, et al., 1985.

^{1/}Agronomy Department, University of Georgia, Athens, GA 30602.

Literature Cited

- Balauch, S. J., S. C. Stratton, and R. J. Buker. 1980. Registration of Forager tall fescue. *Crop Sci.* 20:670.
- Buckner, R. C. 1985. The fescues. p. 233-240. In M. E. Heath, R. F. Barnes, and D. S. Metcalfe (ed.) *Forages - The science of grassland agriculture* (4th edition). Iowa State University Press, Ames, IA.
- Buckner, R. C., J. A. Boling, P. B. Burrus, Jr., L. P. Bush, R. W. Hemken, and M. R. Siegel. 1985. Johnstone tall fescue. Univ. Kentucky Coll. Agric. Spec. Rpt. 1-85.
- Daniel, D. W., J. P. Mueller, and J. T. Green. 1983. Forage crops testing 1982. North Carolina Agric. Ext. Ser. *Crop Sci. Rept.* No. 91.
- Daniel, D. W., J. P. Mueller, and J. T. Green. 1985. Forage crops testing 1984. North Carolina Agric. Ext. Ser. *Crop Sci. Rept.* No. 99.
- Pedersen, J. F., C. S. Hoveland, and R. L. Haaland. 1982. Performance of tall fescue varieties in Alabama. Alabama Agric. Exp. Stn. Circ. 262.
- Pedersen, J. F., J. A. McGuire, S. P. Schmidt, C. C. King, Jr., C. S. Hoveland, and L. A. Smith. 1986. New Zealand J. Exp. Agric. (In Press).
- Reynolds, J. H. 1984. Yield of tall fescue varieties. Univ. Tennessee Res. Rept. 84-04.
- Wilkinson, S. R., J. H. Bouton, D. P. Belesky, J. W. Dobson, Jr., and R. N. Dawson. 1984. Yield of tall fescue cultivars and experimental lines in North Georgia. Univ. Georgia Agric. Exp. Stn. Res. Bull. 319.

EXPLORING THE PLANT-ANIMAL INTERFACE - DIET
SELECTION, CANOPY STRUCTURE AND INTAKE
MEASUREMENT PROBLEMS AND SOLUTIONS

J. R. Forwood¹

In attempting to develop improved systems of producing beef or milk, it is not enough to show a difference between two systems or treatments. Our goal is to discover the "whys" and as completely as possible to understand and explain the forage-livestock responses.

Defining how livestock select species or plant parts in the pasture should aid in understanding why they perform the way they do. To date, esophageal fistulation is accepted as the most accurate method of assessing animal selection but is not utilized by many scientists because of the labor and cost of maintaining research animals. Another major concern is poor animal health and death loss due to the combined surgical and cannulation procedures. Many cannulas with metal sleeves cause esophageal "depression" or "pocketing" with pressure on the interior of the esophagus by the edges and ends of the cannula sleeves. The pressure causes irritation, pressure necrosis, restricted blood supply, mucosal surface erosion and accumulation of granulated and fibrous tissue which results in loss of peristaltic action and eventual starvation. Advances have been made with lightweight materials such as polyethylene (Denny, 1981) and flexible silicone (Ellis et al., 1984). We have developed a one-piece cannula (modified ileal plastisol cannula-MPI) that combines the positive attributes of many existing cannulas (Forwood et al., 1985) (Figure 1).

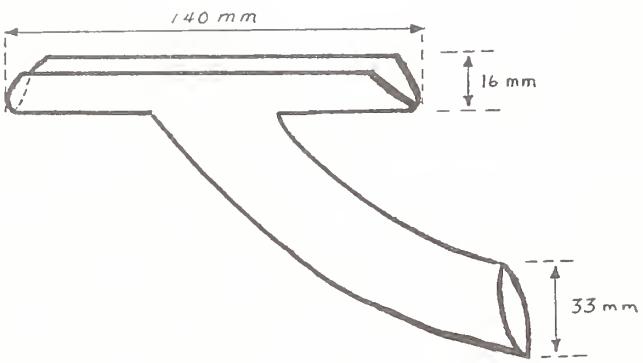


Fig. 1. A one-piece modified plastisol reentrant ileal cannula for use in esophageally fistulated cattle.

Its greatest advantages are (1) reduced esophageal irritation and associated health problems; (2) elimination of accidental swallowing; (3) simple construction; 4) rapid insertion; and (5)

greatly reduced cost. The cost of these cannulas is less than \$1.00 compared to \$35-75.00 for other cannula types. Our studies at Columbia and experience at other institutions has also shown health advantages in coating sleeve-type cannulas with plastisol (Forwood et al., 1985). Hopefully, until an improved method of estimating diet selection is found, these and other advances in the use of fistulated animals will make the technique more palatable to researchers, thereby advancing understanding in this area of research.

It is widely accepted that animal performance on pasture can be improved by overseeding legumes into the sward (Smith et al., 1975; Stricker et al., 1979). Through diet selection of esophageally fistulated animals, we hoped to define cattle preference between red clover (RC), birdsfoot trefoil (BFT), and alfalfa all mixed with orchardgrass at different times of the grazing season, to determine the quantity selected and to relate the above to steer performance. Although data analysis is not complete, it appears the animals prefer BFT (10.9%) over RC (6.24%) in the spring and fall and perform at a higher level on BFT. Selection of legumes by steers was roughly 5 to 7 percentage points above that available in the pasture (1.67 and 3.95% available red clover and birdsfoot trefoil, respectively). On occasion when steers were turned into ungrazed pasture having significantly greater legume content than previous pasture, selected legume percentage remained at approximately the same level. Pasture and diet quality data and other comparisons are not complete, but data such as this may aid in recommending the species preferred by livestock, the one on which they perform best and at what time they prefer it.

Aside from obvious problems in collecting field data with fistulated animals, microhistological analyses of masticated samples is laborious and costly even in a tame pasture situation involving a small number of species. In our situation where essentially one grass and one legume were involved per treatment, we were concerned only with identifying grass and legume percentages consumed. We investigated the use of pinitol (1-D-3-O-methyl-chiro-inositol) concentration in determining legume concentration of esophageal samples as suggested by Smith (1982) in order to overcome the labor, training and cost of microhistological identification.

Found only in legumes and not subject to large plant part and maturity variation, Smith proposed that determination of pinitol concentration in esophageally collected samples of grass-legume mixtures might estimate legume concentration. Results comparing two microhistological methods with pinitol concentration showed the microhistological methods in agreement but that pinitol underestimated the legume component (Table 1). We speculate mastication and salivation are leaching pinitol from the samples and at this point suggest it not be used as a labor and cost saving method in determining legume

¹ USDA-ARS, Research Agronomist and Assistant Professor, U. of MO, Columbia, MO 65211

selection by esophageally fistulated animals (Forwood et al., in review).

Table 1. Average Pasture and Hay Phase Legume Percentages as Estimated by Methods of Sparks and Malechek (SM), Heady and Torrell (HT) and Pinitol Concentration

Pasture Phase	SM	HT	P
Orchardgrass + RC	5.5	7.4	1.5
Orchardgrass + BFT	8.0	10.7	3.6
<hr/>			
Hay Phase			
Orchardgrass + RC	7.0	7.3	1.9
Orchardgrass + Alf	7.1	7.1	1.1

Whether discussing ruminants or monogastrics, quantity of food eaten is the major factor affecting animal productivity. Feed intake by grazers is related to time spent eating, the number of bites per unit of time and the average bite size (Spedding et al., 1976). Attention has been focused on quantity and quality of feed available; however, we may learn considerably about pasture and animal management by studying how sward canopy structure affects animal performance and how animals defoliate the canopy.

Our studies concern (initiated spring 1986) comparison of season-long and complementary grazing systems. We hope to explain performance differences, if any, and gain management insight by measuring leaf and stem ratios, quality and quantity of each, defoliation sequence, intake, bolus size and grazing time. Detailed studies like this may yield valuable information to plant breeders like Dr. D. A. Sleper at the University of Missouri, who has developed low and high leaf area tall fescue types for advanced evaluation with grazers.

While it is important to understand how intake is affected by canopy structure and vice versa, one must realize that we still do not have a direct, accurate and rapid method of measuring intake of free roaming grazers. Thus far the best available methods include estimates of herbage loss from the pasture or animal gain, fecal output and herbage digestibility equations, and indicator methods using chromic oxide or rare earths. More direct methodology has been attempted (Horn and Miller, 1979; Stuth et al., 1981) but nothing has reached the pasture-use stage.

A conductivity transducing cannula (CTC) has been developed and tested which can be placed in the esophagus of fistulated cattle (Forwood et al., 1985). This device signals number of boli swallowed which is positively related to dry matter intake of orchardgrass hay ($r^2=0.81$) and chopped big bluestem grass ($r^2=0.99$) (Table 2). Although the original objective was to measure the exact quantity swallowed (and it may still be achievable), intake measurement by counting

Table 2. Dry Matter Intake (kg) and Number of Bolus Swallows (determined by the CTC device) of Orchardgrass Hay and Chopped Big Bluestem Fed to Confined 1-year-old Esophageally Fistulated Steers

Steer identification	Intake	Number of swallows	r^2
Orchardgrass			
Simmental A	1.22	78	
Simmental A	1.86	97	
Simmental A	1.94	105	0.81
Simmental A	1.97	111	
Angus B	2.05	110	
Angus B	2.07	127	
Big Bluestem			
Angus B	0.68	44	
Angus B	0.73	46	0.99
Angus B	1.02	57	

boli numbers is the current method. This method assumes uniform bolus weights over various herbage species, herbage maturities and animal sizes. Existing studies in confinement show bolus weight to vary among studies, cows and feeds (Schalk and Amadon, 1928; Bailey, 1961; and Gill et al., 1966) while Stuth and Angell (1982) found herbage allowance, cow size and seasons of the year had no significant effect on bolus weight under grazing conditions. Preliminary information under grazing in Missouri (Forwood, unpubl.) indicates a positive relationship between bolus size and animal size and an interaction between small steers and seasons but none between large steers and seasons. Further data are needed, but indications are that if bolus counting is to accurately measure intake, calibration for animal size and forage type may be necessary.

Additional modifications of the CTC device are currently underway. It appears a thermistor will detect boli numbers just as accurately as electrodes and may lend itself to a very minor surgical installation as opposed to the more radical fistulation procedure. Studies on pasture are being planned for the 1986 grazing season with either animal-carried digital readout data storage modules or telemetry devices interfaced with the intake device.

The studies mentioned above and their obvious difficulty "requires that the interface itself be identified as the focal point for investigation, rather than simply as the common boundary between adjacent sectors of interest" (Hodgson, 1985). A great deal of basic and applied research will have to be done not only in exploration of the interface but in order to develop the methodology and instrumentation which will allow rapid and accurate exploration of the area.

Literature Cited

- Bailey, C. B. 1961. Saliva secretion and its relation to feeding in cattle. *Brit. J. Nutr.* 15:433-451.
- Denny, G. D. 1981. A modification of an esophageal fistula plug that allows low maintenance of free-ranging sheep and goats. *J. Range Manage.* 34:152-153.
- Ellis, W. C., E. M. Bailey, and C. A. Taylor. 1984. A silicone esophageal cannula; its surgical installation and use in research with grazing cattle, sheep or goats. *J. Anim. Sci.* 59: 204-209.
- Forwood, J. R., J. L. Ortbals, G. Zinn and J. A. Paterson. 1985. Cannula adaptations for esophageally fistulated cattle. *J. Range Manage.* 38(5):474-476.
- Forwood, J. R., M. M. Hulse, and J. L. Ortbals. 1985. Electronic detection of bolus swallowing to measure forage intake of grazing livestock. *Agron. J.* 77:969-972.
- Gill, J., R. C. Campling, and D. R. Westgarth. 1966. A study of chewing during eating in the cow. *Brit. J. Nutr.* 20:13-23.
- Hodgson, J. 1985. The significance of sward characteristics in the management of temperature sown pastures. XV International Grassland Congress; Plenary Session, Kyoto, Japan.
- Schalk, A. F., and R. S. Amadon. 1928. Physiology of the ruminant stomach (Bovine): Study of dynamic factors. *N. Dak. Agric. Exp. Stn. Bull.* 216.
- Smith, A. E. 1982. Determining the legume-fraction of a grass-legume pasture by pinitol analysis. *Agron. J.* 74:157-159.
- Smith, H., V. L. Lechtenberg, D. C. Petritz, and K. G. Hawkins. 1975. Performance of cows grazing orchardgrass, fescue or fescue-legume. *J. Anim. Sci.* 41:339 (Abstr.).
- Spending, C. R. W., R. V. Large, and D. D. Kydd. 1966. The evaluation of herbage samples by grazing animals. Proc. 10th International Grassland Congress, Helsinki. pp. 474-483.
- Stricker, J. A., A. G. Matches, G. B. Thompson, V. E. Jacobs, F. A. Martz, H. N. Wheaton, H. D. Currence, and G. F. Krause. 1979. Cow-calf production on tall fescue-ladino clover pastures with and without nitrogen fertilization or creep feeding spring calves. *J. Anim. Sci.* 48:13-16.
- Stuth, J. W., K. J. Kanouse, J. F. Hunter and H. A. Pearson. 1981. Multiple electrode impedance plethysmography system for monitoring grazing dynamics. *Biomed. Sci. Instr.* 17:121-124.
- Stuth, J. W. and R. F. Angell. 1982. Effect of seasonal herbage allowance on bolus weights of cattle. *J. Range Manage.* 35:163-165.

CANOPY STRUCTURE EFFECTS ON INGESTIVE BEHAVIOR

J. E. Moore¹, and L. E. Sollenberger²

THE PLANT-ANIMAL INTERFACE

Interactions between forage plants and animals during consumption of forages are being described as the "plant-animal interface." The interactions involve (1) effects of forage characteristics upon intake, digestibility, efficiency of nutrient utilization, and animal performance, and (2) effects of defoliation by grazing animals upon regrowth, persistence, and composition of pasture or range swards. The quantity and character of the forage on offer determines the amount and composition of pasture consumed by the grazing animal, and the very act of consumption influences the quantity and character of the residual forage (Minson, 1983; Moore, 1983; Forbes et al., 1985).

Plant Component

The plant component of the interface may vary in terms of (1) quantity aspects, e.g., herbage mass (kg ha^{-1}) or herbage allowance (kg animal^{-1}), and (2) quality aspects, that is, characteristics of the plant which determine quality, e.g., chemical composition, physical characteristics (plant anatomy and morphology), and, in grazed pastures, canopy structure. Measures of canopy structure include canopy height and canopy profile, i.e., vertical distribution of herbage in terms of bulk density, percentage leaf, percentage green, and percentage of each species in mixed swards.

Animal Component

The animal component includes a large number of factors, but among the most important are those that limit forage dry matter (DM) intake. Three mechanisms of intake limitation have been described: (1) metabolic, (2) distention, and (3) behavioral (Hodgson, 1985).

In the metabolic control mechanism,

$$\text{DM Intake} = (\text{DE Intake}) / (\text{DE Concentration})$$

and DE intake has an upper limit such that increases in DE concentration result in decreases in DM intake. This mechanism may apply to very high-quality forages (Waldo, 1986). In addition, lack of nutrients such as protein or certain minerals may depress intake through some metabolic limitation.

In the distention control mechanism,

$$\text{DM Intake} = (\text{Fill}) / (\text{Retention Time})$$

and fill has an upper limit such that decreases

in retention time (or increases in rates of digestion, degradation and passage) result in increases in DM intake. This mechanism is presumed to account for much of the variation among barn-fed forages where increases in forage maturity are associated with decreases in voluntary intake (Waldo, 1986).

Under grazing, ingestive behavior of animals may override either of the other two intake control mechanisms. In the behavioral control mechanism (Hodgson, 1982),

$$\text{DM Intake} = (\text{Bites per day}) * (\text{Bite weight})$$

where: Bites per day = (Grazing time) * (Bite rate)
Grazing time = min per day
Bite rate = bites per minute

In many cases, bites per day has an upper limit set by either grazing time or bite rate. Compensatory increases in grazing time and bite rate may occur when bite weight declines, but bite weight has a major effect upon DM intake. Rate of total grazing jaw movements varies little, and variations in bite rate occur due to variations in the proportion of jaw movements which are bites (Penning et al., 1984). Black and Kenney (1984) reported that "prehending" bites ranged from 20 to 80% of total jaw movements in sheep. Chambers et al. (1981) observed ratios of 1.1 to 1.7 jaw movements per bite with sheep and cattle, which are comparable to 47 to 37 bites per 100 jaw movements. If there is variation in bites per 100 jaw movements, estimates of bites per minute and bite weight based only on records of total jaw movements may not be accurate.

No doubt there are shifts from one intake control mechanism to another in grazed pastures due to the effects of the animal upon the plant. As higher-quality forage is removed, distention may replace metabolic factors as an intake limit. When bite weight is not limiting, then intake may be determined by the chemical and physical characteristics of the ingested forages (Chacon et al., 1978). If the rate of herbage consumption exceeds the rate of regrowth, a lack of available forage may make it impossible for the animal to consume enough to meet the limit set by distention. When bite weight is limited by lack of available or accessible forage, then intake and animal performance may be depressed (Ludlow et al., 1982).

CANOPY STRUCTURE, INGESTIVE BEHAVIOR, AND DIET COMPOSITION

In some cases the structure of the canopy may override distention or metabolic limits, and intake is depressed due to behavioral limitation (Ludlow et al., 1982). Although it may be misleading to generalize about the relationships between canopy structure and ingestive behavior, Hodgson (1985) suggested that for temperate pastures, bite weight is positively related to herbage mass, canopy height, and bulk density. There may be negative relationships, however, among those same measures of canopy structure.

¹Animal Science Department

²Agronomy Department

University of Florida, Gainesville, 32611

Tropical grass pastures are characterized by low canopy densities and low leaf area densities (Ludlow et al., 1982). The low leaf area density tends to result in decreased bite weight and decreased intake. Animal performance on such pastures is not easily predicted from canopy characteristics, but important considerations are those that influence bite weight and nutritive value of the diet selected (Chacon et al., 1978). There may be a negative relation between bite weight and nutritive value, however, suggesting that selection and intake may be influenced by different characteristics of the canopy.

Legume-Grass Pastures

Although there has been little work on grazing behavior and diet quality of tropical legume-grass pastures, it may be presumed that the presence of legume in grazed horizons would increase animal performance (Reed, 1981) by increasing intake, perhaps by increasing bite weight, or by increasing nutritive value of the diet selected. Animals on pasture graze selectively and generally consume forage of higher nutritive value (protein and digestibility) than that of the total forage on offer (Arnold, 1980). In some cases, sheep grazing a white clover-ryegrass sward selected a diet higher in clover than was in either the total canopy or the portion of the canopy being grazed (Milne et al., 1982). On red clover-ryegrass pastures, sheep selected clover leaf especially when the canopy was grazed down quickly (Laidlaw, 1983). In a tropical savanna, cattle selected legumes to a greater extent during the dry season when green grass leaves were unavailable, than they did during the rainy season (Bohnert et al., 1985).

The effect of legume must be tested for specific associations because it has not been demonstrated that animals express nutritional wisdom when given a choice of dietary components (Arnold, 1980), and unpalatable constituents in certain legumes may cause animals to select grass rather than legumes (Marten, 1981). Examination of canopy profiles and botanical composition of herbage consumed by grazing animals will provide very useful information for interpretation of the plant-animal interface.

Florida Research

We conducted a grazing study to determine the effects of variations in canopy characteristics of Hemarthria altissima (limpograss)-Aeschynomene americana (jointvetch) pastures upon ingestive behavior and diet botanical composition of esophageal-fistulated steers (Moore et al., 1985), and upon the botanical composition of herbage consumed during an entire grazing period. The study was superimposed upon a larger management study (Sollenberger et al., 1985) in which 0.05-ha pastures were grazed rotationally with five weeks rest and two days grazing.

Two pastures varying in herbage mass and canopy structure were selected on each of 12 weeks, giving a total of 24 observations. Prior to

grazing, canopy structure was characterized by clipping five, 0.5 m² sites per pasture in 10-cm layers, and separating herbage into legume, grass, and weed components. Calculations were made of botanical composition of whole canopy and two canopy fractions: upper layer, which was the top 20 cm (or 10 cm in short pastures but never the bottom 10 cm), and grazed horizon, which was the herbage above 10 cm for pastures less than 60 cm tall but that above 30 cm for pastures from 80 to 100 cm tall.

Ingestive behavior was measured with four esophageal-fistulated steers during 20-min collections after the animals were first placed on pastures at the start of grazing periods. Extrusa were collected in screen-bottom bags. Total jaw movements were measured electronically, and actual bites (forage being severed) were recorded by hand when a jaw movement was associated with the sound of forage being severed. Additional steers were added for the remainder of the grazing period.

Following grazing, samples of residual forage were separated into legume, grass, and weeds. The percentage legume in consumed herbage was calculated as follows:

$$\frac{(\text{Pregraze-Postgraze Legume Herbage Mass})}{(\text{Pregraze-Postgraze Total Herbage Mass})} \times 100$$

$$\frac{\text{Pregraze-Postgraze Total Herbage Mass}}{\text{Canopy Character}}$$

Bulk density of the legume was fairly constant throughout the canopy but density of grass increased from top to bottom of the canopy. In the whole canopy, percentage legume was always less (0.7 to 38.3) than that of grass (46.4 to 93.5). Legume as a percentage of the total of legume plus grass averaged 19.6, but ranged from 1.0 to 44.8. Legume percentages in upper layer and grazed horizon were correlated with that in whole canopy, but that in the upper layer was about twice that in the canopy as a whole.

Ingestive Behavior

Total grazing jaw movements varied from 50.1 to 76.8 per minute and there were no differences among pastures or animals. For 19 of the 24 pastures, means were between 62 and 72 per minute, which are similar to, or slightly higher than, values reported by Chacon and Stobbs (1976) for "rate of biting." The number of bites per minute (forage being severed) varied from 19.7 to 37.5. The correlation between bites per minute and total jaw movements per minute was low ($r=.29$, $n=76$, $P<.05$). Bites per 100 jaw movements varied from 27.9 to 59.0 with lower values indicating a greater proportion of total jaw movements associated with either mastication or manipulation of forage prior to biting and(or) swallowing. Our observations in the field support the conclusion that the major non-biting activity was associated with gathering herbage prior to biting, rather than with mastication during grazing or manipulation of severed forage in the mouth prior to swallowing. Legume percentage in extrusa was

higher when ingestive behavior involved an increase in manipulative activity.

In general, our data suggested that intake per minute was more closely related to bite weight than to bites per minute, or to the proportion of jaw movements which were bites. Similar results were found by Chacon and Stobbs (1976) and Black and Kenney (1984). On the other hand, there was a close relationship between legume percentage in the diet and the proportion of jaw movements which were bites. At the beginning of a grazing cycle, therefore, intake rate and legume content of the diet may be independent of each other and affected by different characteristics of the canopy.

Canopy Character vs. Ingestive Behavior

Neither legume bulk density nor percentage in the upper layer affected bite weight. The major factor affecting bite weight was the percentage of green herbage in the upper layer ($r=.75$). Intake per minute was positively related to both the percentage of green herbage in the upper layer ($r=.62$) and to legume leaf as percentage of total legume in the upper layer ($r=.61$). Chacon et al. (1978) and Jamieson and Hodgson (1979) found a positive relationship between green herbage mass and bite weight in grass pastures, and Hendrickson and Minson (1980) found a similar relationship with *Lablab purpureus*. Ebersohn et al. (1985) found a negative relationship between non-green herbage and liveweight gain.

Total jaw movements per minute were not related to any characteristic of the canopy. However, bites per minute tended to increase as a result of decreasing legume percentage, increasing weed percentage, and increasing total leaf percentage in the upper layer (multiple $R^2=67.9$). There was a negative relationship between total herbage mass and bites per minute ($r=-.54$). There was a negative relationship between percentage legume in the upper layer and bites per 100 jaw movements ($r=-.68$), indicating an increase in manipulative activity when legume percentage was high. These data suggest that at least part of the mechanism of selection for legume (i.e., when legume in the diet is a higher percentage than that in the upper layer) may involve an increased gathering activity prior to biting (severing) herbage.

Canopy Character vs. Diet Composition

In the extrusa, legume ranged from 1.3 to 93.4% of DM and was positively related to legume percentage in the upper layer ($r=.85$). In all but five pastures, legume in the extrusa was equal to or higher than that in the upper layer. Those five pastures were sampled at the end of the season and had high bulk density of weeds. When the five most weedy pastures were eliminated, there was a quadratic relationship between legume percentage in the extrusa and in the upper layer ($R^2=.88$). When legume in upper layer was 40% or more, legume in extrusa was 70% or more.

Legume percentage in extrusa was higher than that in grazed horizon, but that in the herbage consum-

ed (as calculated by the difference method) was almost identical to that in grazed horizon. The following are correlations (R^2) among percent legume in various fractions:

Consumed vs.	Whole canopy	.93
	Grazed horizon	.91
	Upper layer	.86
Esophageal vs.	Whole canopy	.49
	Grazed horizon	.55
	Upper layer (Q)	.67
	Consumed	.44

Laidlaw (1983) found that sheep continued to select legume throughout the grazing period. In our study, however, there was no evidence for selection within the grazed horizon when the entire grazing period was considered. Generalizations from results on one legume-grass association to another might be misleading.

Conclusions

In our study, there appeared to be at least two separate phenomena at the plant-animal interface when cattle first grazed the association: one related to bite weight, the other related to legume percentage of the diet selected.

Bite weight was lower when pastures were shorter and more dense, and when there was a high proportion of dead matter in the upper layer. These conditions occurred primarily late in the season when pastures had been grazed several times. There was no effect, however, of legume percentage in the upper layer upon bite weight, and bites per 100 jaw movements were not closely related to bite weight.

Esophageal-fistulated animals consumed a diet with a higher legume percentage than that found in the upper layer of clipped sites in all but the most weedy pastures. Our data and observations suggest that steers responded to increased legume percentage in the upper layer by increasing manipulative activity prior to biting, i.e., decreasing bites per 100 jaw movements and rate of biting. The manipulation served to increase the percentage of legume in each bite over that in the upper layer of the canopies.

Legume percentage of consumed herbage, determined by the difference method, showed evidence for selection, in that legume percentage of consumed herbage was higher than that of the whole canopy prior to grazing. There was excellent agreement, however, between the legume percentage of the grazed horizon and that of consumed herbage. It may be that, with this legume-grass association under rotational management, cattle removed legume leaf from the canopy first, then began to consume whatever grass and legume remained in the grazable horizons. These data are evidence of a dynamic plant-animal interface in that canopy characteristics influenced the diet quantity and character, the act of consumption changed the canopy, and animals responded by altering their degree of selection. These observations may be

valid, however, for only this association studied in this particular manner.

In comparing pasture sampling by using esophageal-fistulated steers with use of the agronomic or difference method, it appears that esophageal samples are useful for "strategic" examination of diets at particular times during rotational or continuous grazing, whereas the difference method is useful for obtaining an "integrated" sample of herbage consumed during rotational grazing.

RECOMMENDATIONS

For those who consider conducting studies of the plant-animal interface in grazed pastures, the following recommendations should be considered:

1. Establish a strong justification for conducting the study. Such studies are demanding, and should not be undertaken without sufficient reason.
2. Develop clear objectives for each particular study, and design the trial to meet just those objectives. Each study should try to answer a specific question rather than synthesize broad generalities.
3. Make an extra effort to measure important response variables. Measure herbage mass, and characterize the canopy profile thoroughly in terms of botanical composition and bulk density. Observe animal behavior carefully, and make accurate counts of actual bites. It is not always necessary to use esophageal-fistulated steers for such measurements, and observation of intact animals at frequent intervals may be more meaningful than those obtained during short collections. Use esophageal-fistulated steers strategically to measure diet composition and bite weight at particular times during the grazing cycle. Use large fistulas so that samples are representative of the diet consumed and so that bite weight is not underestimated.

Literature Cited

- Arnold, G. W. 1980. Grazing behavior. In (F. H. W. Morley, Ed.) *Grazing Animals*. Elsevier, Amsterdam. pp. 79-104.
- Black, J. L., and P. A. Kenney. 1984. Factors affecting diet selection by sheep. II. Height and density of pasture. *Aust. J. Agric. Res.* 35:565-578.
- Bohnert, E., C. Lascano, and J. H. Weniger. 1985. Botanical and chemical composition of the diet selected by fistulated steers under grazing on improved grass-legume pastures in the tropical savannas of Colombia. I. Botanical composition of forage available and selected. *Z. Tierzuchtg. Zuchtgbiol.* 102:385-394.
- Chacon, E. A., and T. H. Stobbs. 1976. Influence of progressive defoliation of a grass sward on the eating behaviour of cattle. *Aust. J. Agric. Res.* 27:709-727.
- Chacon, E. A., T. H. Stobbs, and M. B. Dale. 1978. Influence of sward characteristics on grazing behavior and growth of Hereford steers grazing tropical grass pastures. *Aust. J. Agric. Res.* 29:89-102.
- Chambers, A. R. M., J. Hodgson, and J. A. Milne. 1981. The development and use of equipment for the automatic recording of ingestive behaviour in sheep and cattle. *Grass Forage Sci.* 36:97-105.
- Ebersohn, J. P., K. W. Moir, and F. Duncalf. 1985. Inter-relationships between pasture growth and senescence and their effects on live-weight gain of grazing beef cattle. *J. Agric. Sci., Camb.* 104:299-301.
- Forbes, T. D. A., E. M. Smith, R. B. Razor, C. T. Dougherty, V. G. Allen, L. L. Erlinger, J. E. Moore, and F. M. Rouquette, Jr. 1985. The plant-animal interface. In (V. H. Watson and C. M. Wells, Eds.) *Simulation of Forage & Beef Production in the Southern Region*. Southern Cooperative Series Bull. 308. pp. 95-116.
- Hendrickson, R., and D. J. Minson. 1980. The feed intake and grazing behaviour of cattle grazing a crop of *Lablab purpureus* cv. Rongai. *J. Agric. Sci., Camb.* 95: 547-554.
- Hodgson, J. 1982. Ingestive behavior. In (J. D. Leaver, Ed.) *Herbage Intake Handbook*. Brit. Grassl. Soc., England. Chapter 6, pp. 113-138.
- Hodgson, J. 1985. The control of herbage intake in the grazing ruminant. *Proc. Nutr. Soc.* 44:339-346.
- Jamieson, W. S., and J. Hodgson. 1979. The effects of variation in sward characteristics upon the ingestive behavior and herbage intake of calves and lambs under a continuous stocking management. *Grass Forage Sci.* 34:273-282.
- Laidlaw, A. S. 1983. Grazing by sheep and the distribution of species through the canopy of a red clover-perennial ryegrass sward. *Grass Forage Sci.* 38:317-321.
- Ludlow, M. M., T. H. Stobbs, R. Davis, and D. A. Charles-Edwards. 1982. Effect of sward structure of two tropical grasses with contrasting canopies on light distribution, net photosynthesis and size of bite harvested by grazing cattle. *Aust. J. Agric. Res.* 33:187-201.
- Marten, G. C. 1981. Effect of deleterious compounds on animal preference for forage and on animal performance. In (J. L. Wheeler and R. D. Mochrie, Eds.) *Forage Evaluation: Concepts and Techniques*. American Forage and Grassland Council, Lexington, KY. pp. 225-235.

Milne, J. A., J. Hodgson, R. Thompson,
W. G. Souter, and G. T. Barthram. 1982.
The diet ingested by sheep grazing swards
differing in white clover and perennial
ryegrass content. *Grass Forage Sci.*
37:209-218.

Minson, D. J. 1983. Forage quality: Assessing
the plant-animal complex. *Proc. XIV*
International Grassland Congress, Lexington,
KY. pp. 23-27.

Moore, J. E. 1983. Remarks of discussion
leader (see Minson, 1983). *Proc. XIV*
International Grassland Congress, Lexington,
KY. pp. 27-28.

Moore, J. E., L. E. Sollenberger, G. A.
Morantes, and P. T. Beede. 1985. Canopy
structure of Aeschynomene americana -
Hemarthria altissima pastures and ingestive
behavior of cattle. *Proc. XV International*
Grassland Congress, Kyoto, Japan. (In press).

Penning, P. D., G. L. Steel, and R. H. Johnson.
1984. Further development and use of an
automatic recording system in sheep grazing
studies. *Grass Forage Sci.* 39:345-351.

Reed, K. F. M. 1981. A review of legume-based
vs nitrogen-fertilized pasture systems for
sheep and beef cattle. In (J. L. Wheeler
and R. D. Mochrie, Eds.) Forage Evaluation.
Concepts and Techniques. American Forage
and Grassland Council, Lexington, KY.
pp. 401-417.

Sollenberger, L. E., K. H. Quesenberry, G. O.
Mott, and J. E. Moore. 1985. Effects of
grazing management on production and forage
quality of a limpograss-jointvetch
association. *Proc. Forage and Grassland*
Conf., American Forage and Grassland Council,
Hershey, PA. pp. 79-83.

Waldo, D. R. 1986. Effect of forage quality
on intake and forage-concentrate inter-
actions. *J. Dairy Sci.* 69:617-631.

SUMMARY OF REGIONAL PROJECT S-156, SIMULATION OF FORAGE AND BEEF PRODUCTION IN THE SOUTHERN REGION

L. M. Tharel¹, M. A. Brown¹, and E. M. Smith²

Approximately 25.0 million hectares of pastureland and native pasture, and about 50% of the nation's beef cattle are located in the South. The value of production for beef cattle in recent years exceeds 7 billion dollars annually. Pasturelands are most often associated with beef production systems and most beef animals begin and spend the majority of their time on pastures. Forage crops are basic elements of pastures and constitute the primary feed source for beef cattle. (Little, 1985).

The management of these pastures and the beef animals which utilize the feed produced by these pastures is an important issue in planning and executing beef cattle production systems. Research should provide the fundamental knowledge which can be used as a basis for developing management strategies which have the highest probability of success in particular situations. There are literally as many production systems as there are beef producers, and for each of these systems there are many management strategies which need to be evaluated in order that producers in each situation can effectively utilize resources to produce feed for animals and produce a marketable product. The use of traditional field experiments to evaluate a large number of management strategies (Smith and Williams, 1973) simultaneously for many different production situations (Tseng and Mears, 1975) is impractical, because such experiments would require an enormous commitment of money, land, and scientific man-years (Smith, et. al., 1985).

Research has contributed significantly to the development of forage-beef production systems and much research continues to be directed toward current problems and potentials. With the importance of forage-beef production, attention continues to be directed to evaluating past research, identifying and prioritizing new research and increasing the flow of results toward application. Excellent results from much good research are available. Systems research in agriculture has advanced less than have industrial and commercial applications. Possibly because of the size and diversity of the agricultural sector and the predominance of small owner-operated farms (Dent and Blackie, 1979). Scientists and producers have consistently identified an

increasing need for putting the pieces together so as to understand better the entire forage-beef production system. Climatic, soil, and economic conditions in the Southern Region, although varied, present great opportunities for forage production throughout most of the year. These conditions, problems and opportunities presented a special situation for interaction between scientists from several disciplines to work together in a coordinated effort. In July 1978 a Southern Region Livestock-Forage Review Committee identified this situation and stated:

"Systems research is needed to delineate and solve the problems associated with different livestock-forage production systems and to determine income-producing capabilities of the different systems. Systems research is needed to determine the performance of livestock-forage systems when they interact with various resource and management constraints. Computer technology can now allow for the development of a simulation model of the complicated interrelations of the many variables within the system. A simulation research model, properly validated by data from specific research projects, can be used as an artificial laboratory to study livestock-forage production systems. The information generated by such a model will point up the 'gaps' in the research data that are needed to be part of any management decision concerning the ¹livestock-forage production systems."

Southern Cooperative Regional Project S-156 was initiated in January 1981 to speak to this expressed need with the following general objectives:

1. To refine mathematical-logical relationships currently existing in a comprehensive systems model, so that the model can be used in the southern region.
2. To facilitate use of the comprehensive systems model to obtain new knowledge concerning forage-beef production within the constraints imposed by the resources in the Southern Region.

The S-156 project entitled "Simulation of Forage-Beef Production in the Southern Region", involved scientists with specialization in Agronomy, Animal Science, Agricultural Economics, Agricultural Engineering, Statistics and Veterinary Entomology from 10 State Agricultural Experiment Stations and four USDA-ARS Laboratories. Considerable time has been spent interacting in groups and subgroups to conceptualize forage-beef production systems, to assimilate the results of basic research defining the entities and sub-entities

¹Agricultural Research Service, U.S. Department of Agriculture, South Central Family Farm Research Center, Booneville, Arkansas.

²Agricultural Engineering Department, University of Kentucky, Lexington, Kentucky.

¹Recommended Adjustments in Livestock-Forage Research in the Southern Region - Report of the Livestock-Forage Review Committee, Southern Region, U.S.A. July 1978, p21.

which interact, to construct mathematical logic, incorporating this knowledge into simulation models and to evaluate these simulations in "real world" comparisons. Individual participants have authored numerous publications in the professional journals of their disciplines. Vacuums of knowledge critical to refining forage-beef production systems have been and are being identified and incorporated into specific projects by one or more discipline groups. Approximately a dozen states have set up the mechanics for using the simulation models for program planning and evaluation and for education and training experiences (Little, 1985).

As a result of the Regional emphasis, plant and animal sub-models were developed. As the sub-models were developed, they were in some instances, incorporated. Loewer and Smith (1986) have briefly characterized the models which are a result of S-156.

GROWIT (Version 2) - This is a model of plant growth that utilizes maximum and minimum temperature, rainfall, soil fertility, harvesting and other cultural practices in describing plant growth. It simulates grazing rate through various harvesting options. Version 2 of GROWIT is more basic to plant growth physiology and incorporates cell content and cell wall logic with plant physiological age to define potential digestibility.

BEEF-S156 - This model is based on the concept of physiological growth as expressed through changes in body composition. Intake may be altered by control mechanisms associated with thermostatic and chemostatic limits, physical fill, and night-time limits. The time step is a user-defined input but is usually not greater than 15 minutes.

GRAZE - The GRAZE model incorporates selective grazing logic with the plant growth concepts of GROWIT (Version 2) and the animal growth concepts of BEEF-S156. GRAZE utilizes selective grazing logic that allows the animal to graze partial areas within a pasture. The basic assumptions are that a grazing animal will attempt to maximize its digestibility dry matter intake rate, and that total dry matter availability per unit area of land will, at some point, begin to limit intake rate. The GRAZE model has received testing using field studies from Mississippi and Georgia, and the model is performing well in both instances.

Companion animal models developed as graduate theses projects in Agricultural Engineering at the University of Kentucky include BEEFEM and SAM.

BEEFEM is a finite element model of the interior of a beef animal that simulates the flow of heat as influenced by environment, activity, and digestion. This model was calibrated and tested using beef animals with implanted temperature devices in environmental

chambers. Contaminated fescue was fed as one of the test rations. The model indicates that vasoconstriction may be the mechanism that limits intake for animals fed this ration.

SAM - SAM is a static model that utilizes body measurements and geometric shapes in determining beef animal surface area. The purpose of the model is to enhance the ability to describe heat flows to and from the animal. This model was superior to the most commonly used empirical models over the age range of animals tested.

PASTURE - PASTURE is the most recent update of GROWIT (Version 2). It has been structured specifically for stochastic simulation of grazing systems. In structuring this model, special consideration has been given to keeping the input data file brief, yet, allow sufficient flexibility to adequately describe different grazing management systems. In addition, the data output file was simplified to enhance data management and analysis. The model logic used in the simulation of potential tissue production is based on ruminant protein requirements (ARC, 1980) and digestible dry matter and dietary nitrogen adapted from a model by Greenhalgh (1981).

The model is structured to allow grazing systems to be described in terms of 1) number of fields, 2) rotation period in days, 3) simulated grazing rate in kg/ha/da or 1b/ac/da, and number of grazing periods per year and the date when each period begins and ends. It allows for hay harvesting at specified times and moisture to be supplied thru irrigation on a specified schedule.

Real weather data provide stochastic variables and any number of consecutive years of weather data can be used as input data. These stochastic variables allow simulations to be replicated, consequently, simulation results may be subjected to statistical analysis.

To conduct a simulation experiment the same thought process is used as if an actual experiment were to be conducted. There are specific initial parameters which must be defined.

INPUTS FOR PASTURE MODEL TO SIMULATE ON EXPERIMENT

- Period of Study; first and last year, duration of study
- Latitude of Site
- Fields; number, day(s) on each
- Grazing Period; number, day(s) of each, beginning and ending date(s)
- Interval between Data Collections
- Cattle; weight, number per ac or ha
- Harvest Efficiency
- Grazing Rates
- Dry Matter Remaining after Grazing
- Climatic Data; precipitation and temperature (max., min.)

- Irrigation Schedule; number, frequency, quantity, date(s)
- Soil Test Data
- Fertilization; N,P,K, date(s), quantity
- Hay Harvest; date(s)

MODEL APPLICATION

St. Louis et. al. (1985) stated that models can be important aids in designing systems research projects by simulation of several forage-beef systems before field trials are initiated. The economic feasibility of alternative systems can be verified, sensitivity and variation of production components can be determined, and important voids in the data base can be identified. Much former research would have broader application if data specific to the environment and management of the project had been reported.

Parsch et. al (1986) conducted a simulation experiment to analyze the impact of weather variability on the economic performance of a beef-forage grazing system. Three stocking rates 2, 7 and 12 hd/ha and 10 years of historical weather data were included as variables. The results indicated that 12 hd/ha produced the highest gain per ha while gain/hd was maximized with the lowest stocking rate, 2 hd/ha; expected net returns per ha were highest under the medium stocking rate; and, the adverse effects of a poor weather season were magnified at the higher stocking rate. Ranking of the three stocking rate strategies showed that the low stocking rate is the most risk-efficient, whereas the medium stocking rate maximizes expected utility of producers who are risk neutral.

St. Louis et. al. (1985) further stated that the plant and animal submodels, or components can be run separately, which makes it possible to study and better understand fundamental relationships that would be very difficult to study without simulation. For example, the model can simulate physiological and chronological age relationships as they relate to plant and animal growth. Since cell-wall content and cell-wall maturity are incorporated as quality indicators in the plant submodel, one can study the combined effects of environment and maturity on forage yield and digestibility. Furthermore, the effects of environment on plant-related determinations of forage quality can be separated from the influences of environment on animal determination of intake, digestibility and use. The animal submodel is a body composition model, thus making it possible to study the combined effects of environment, age, fat storage and nutritional status on animal growth, reproduction, lactation and gestation.

As strategies for meeting management objectives are found through simulation, scientists and managers also will develop an improved understanding of key variables. For example, each management strategy of a forage-beef

production system may result in a different seasonal distribution of feed supply (quantity and quality), which results in seasonal variation in beef production. This may in turn, lead to more efficient resource substitution, such as purchasing of feed supplements. Regional and annual differences in temperature, rainfall, forage production, etc. can all be taken into consideration when optimum management strategies are determined. The crop growth component can simulate growth of warm- and cool-season perennial grasses alone or in combinations, resulting in broad applications of management strategies across the Southern Region. Similarly, the animal component can consider breed differences and influences of weather on animal performance independent of forage quality and availability.

Fick and Onstad (1983) state that models of complex systems are never complete, but they can be used to satisfy specific and reasonable objectives. Models designed for tasks can be improved, extended, modified, updated and simplified to achieve new and different objectives. Because our understanding of forage-livestock systems is limited, all models contain elements based on extrapolation, interpolation and algorithms. As research, possibly directed by systems research, expands knowledge in these areas, approximations can be supplanted by quantitative information. We can expect forage-livestock models to expand and then contract in size as sensitivity analysis weeds out the non-limiting factors, spinning off simpler models that can be used in an interactive mode on microcomputers.

Barnes et. al. (1985) emphasized that mathematical models cannot replace the judgement of experienced people nor can they analyze cause and effect relationships that cannot be quantified. The effectiveness of systems modeling and its application to agriculture depends upon the accuracy, comprehensiveness, and ease of the systems models. We are on the threshold of a new frontier of science that presents a challenge to agricultural scientists and administrators to integrate available knowledge into comprehensive research programs for solving short- and long-term problems.

Literature Cited

- ARC. 1980. The nutrient requirements of ruminant livestock. Commonwealth Agricultural Bureaux, Farnham Royal, Slough 2L2, 3BN, England.
- Barnes, R. F., C. O. Little, and M. A. Brown. 1985. Influence of systems modeling on agricultural policy. In V. H. Watson, and C. M. Wells (Ed.), Simulation of Forage and Beef Production in the Southern Region. So. Cooper. Series, Bull. 308. Miss. St. Univ., Miss. St. MS. pp. 133-134.

Dent, J. B. and M. J. Blackie. 1979. Systems simulation in agriculture. Applied Science Publ. LTD. London.

Fick, G. W., and D. Onstad. 1983. Simulation models for forage-management applications. In J. A. Smith and V. W. Hays (Ed.), Proceedings of the XIV International Grassland Congress, Westview Press, Boulder, CO, pp. 483-485.

Greenhalgh, J. F. D. 1981. A forward look at technical possibilities for grassland. Grassland in the British Economy. CAS Paper 10. Reading: Center for Agricultural Strategy, pp. 51-63.

Little, C. O. 1985. Introduction. In V. H. Watson, and C. M. Wells (Ed.), Simulation of Forage and Beef Production in the Southern Region. So. Cooper. Series, Bull. 308. Miss. St. Univ., Miss. St. MS. pp 1-2.

Loewer, O. J. and E. M. Smith. 1986. Biological description of the Kentucky beef-forage model. In D. Laughlin and T. Spreen (Ed.), Simulation of Beef Cattle Production Systems and its Role in Economic Analysis. Westview Press, Boulder, CO. (In press).

Parsch, L. D., O. J. Loewer, and D. H. Laughlin. 1986. Risk efficiency of beef-forage stocking rates under weather uncertainty. In D. Laughlin and T. Spreen (Ed.), Simulation of Beef Cattle Production Systems and its Role in Economic Analysis. Westview Press, Boulder, CO. (In press).

Smith, E. M., L. M. Tharel, M. A. Brown, C. T. Dougherty, and K. Limbach. 1985. A simulation model for managing perennial grass pastures. Part I - Structure of the model. Agri. Systems. 17, pp 155-180.

Smith, R. and W. A. Williams. 1973. Model development for a deferred grazing system. J. Range Mgmt. 26, pp. 454-460.

St. Louis, D. G., B. W. Spaulding, O. J. Loewer, and V. H. Watson. 1985. Applications and limitations of modeling forage and beef. In W. H. Watson, and C. M. Wells (Ed.), Simulation of Forage and Beef Production in the Southern Region. So. Cooper. Series, Bull. 308. Miss. St. Univ., Miss. St. MS. pp 131-132.

Tseng, W. and D. R. Mears. 1975. Modeling systems for forage production. Trans. ASAE, 18, pp. 206-212.

APPROPRIATE MARKERS AND METHODOLOGY FOR GRAZING STUDIES

K. R. Pond¹, J. C. Burns², D. S. Fisher² and R. A. Quiroz¹

Evaluation of the grazing animal's diet, requires measurement of both the voluntary intake of forage and its nutritive value. Appropriate markers (indicators) have been used to provide information on forage utilization by the animal. Markers have been used to determine forage digestibility, output of feces by the animal, rate of passage (liquids and solids) through the gastrointestinal tract, fill of undigested dry matter and rate of particle size breakdown. The purpose of this paper is to briefly review many of the available markers and recommend procedures for their use in grazing studies. The literature cited should be reviewed for more detailed information.

TYPES OF MARKERS

Markers may be categorized as internal or external. Internal markers are natural constituents of the plant that are neither digested nor absorbed by the animal. Examples include silica, lignin, fecal nitrogen (indigestible nitrogen), chromogens, indigestible neutral detergent fiber and acid insoluble ash.

External markers are not natural constituents of the forage but must also not be digested or absorbed. These markers are fed or otherwise administered to the animal. Examples include chromic oxide, ferric oxide, silver sulfide polyethylene glycol and preparations of chromium, cobalt, hafnium and several rare earth metals.

Internal markers

Internal markers are most commonly used to estimate digestibility. The marker concentration is determined in both the consumed forage and feces. The dry matter digestibility (DDM) is then calculated from the ratio of the marker in the forage (M_{forage}) and feces (M_{feces}) (Schneider and Flatt, 1975):

$$DDM, \% = 100 - \left(100 \times \frac{\% M_{forage}}{\% M_{feces}} \right) \quad (1)$$

The digestion coefficient (DC) of any nutrient can also be estimated by determining the ratio of the nutrient to that marker in the forage (N_{forage}) and feces (N_{feces}):

$$DC, \% = 100 - \left(100 \times \frac{\% M_{forage} \times \% N_{feces}}{\% M_{feces} \times \% N_{forage}} \right) \quad (2)$$

Several internal markers have been researched and are described below.

Silica - Naturally occurring silica in forage is indigestible and recovered in the feces. Silica concentration in the forage has been variable and inconsistent especially in areas where significant soil contamination of the forage is a problem. In addition, poor recovery of silica in the feces has limited its use as an internal marker (Gallup et al., 1945). Silica from soil contamination must be estimated and removed from calculations of DDM and DC.

Lignin - The naturally occurring indigestible portion of the cell wall and middle lamella of forage has been used as an internal marker with reliable results for some species of plants. Ellis et al. (1946) was the first to propose its use as a marker and its gravimetric analysis after 72% H_2SO_4 extraction. Diurnal variation in lignin concentration in the feces can be high, so many samples need to be collected. Reducing the variability in the analysis of this heterogeneous polymer may require analysis of the individual components rather than the present gravimetric procedures for total lignin.

Fecal nitrogen - Holter and Reid (1959) studied the relationship between protein in the feces and digestibility with 79 forages. They concluded that the true digestibility of protein is relatively constant regardless of the concentration of crude protein in forages. Schneider and Flatt (1975) then developed an equation to determine the digestibility of dry matter utilizing crude protein in forage and feces. This equation has not been evaluated for many forage species.

Chromogens - Plant pigments, "chromogenic substances", are soluble in 80% acetone. Concentrations are determined spectrophotometrically and are completely recovered in the feces. This method is described by Reid et al. (1950 and 1952). Chromogens, as markers, seem to be best fitted to lush growing forage and least effective for drought or temperature stressed poorly pigmented plant tissues.

Indigestible neutral detergent fiber (INDF)
The neutral detergent fiber residue after in vitro fermentation for 144 to 196 h has been

¹Department of Animal Science, N.C. State University, Raleigh, NC 27695-7621

²Agricultural Research Service, U. S. Department of Agriculture, Plant Science Research Unit and Department of Crop Science, N. C. State University, Box 7620, Raleigh, NC 27695-7620.

used as an internal digestibility marker (Lippke et al., 1986). Variable recovery of INDF and a "recovery x particle size" interaction are potential problems with the technique. However, several investigators have utilized INDF as a marker in grazing studies.

Acid insoluble ash (AIA) - The insoluble ash after acid hydrolysis (Thoney et al. 1985) has been used as an internal marker in feedlot diets and with animals consuming Coastal bermudagrass. The concentration of AIA in most forages is low. Therefore, the sample of forage and feces required for the analysis is larger than with other markers (10-25g required).

An infallible and dependable internal marker is not available at this time. Of these markers, lignin has been the most widely used. In our lab, components of lignin resistant to strong alkali hydrolysis are being evaluated as possible internal markers. A reliable internal marker would be a significant contribution to the understanding of plant-animal dynamics in grazing research.

External markers

External markers have been most frequently used to estimate output of feces. With knowledge of the dry matter digestibility (DDM) of the forage, the voluntary intake (VI) of the animal can be calculated:

$$VI, \text{ g/d} = \frac{\text{dry matter output of feces, g/d}}{1 - (\text{DDM}/100)} \quad (3)$$

Although the total output of feces can be collected with a fecal bag and collection harness, it is laborious and unsatisfactory for most grazing studies (especially during the spring or when forage quality is high). Alternatively, fecal output can be computed without total collection by using indigestible markers. There are two methods: daily marker administration to generate a steady state or single (pulse) dose administration.

In the first method, daily administration of a known quantity of a marker is followed by periodic sampling of feces. The marker concentration in the feces is then determined. Equilibrium (steady state conditions) of the marker, requires administration for at least five days prior to sampling. Grab samples of feces should be collected over 3- to 7-days to obtain a mean marker concentration. Diurnal variation has been reported for several markers so multiple sampling times are required. Fecal output (FO) is then calculated as follows:

$$FO, \text{ g/d} = \frac{\text{marker administered, } \mu\text{g/d}}{\text{marker concentration in feces, } \mu\text{g/g}} \quad (4)$$

This procedure has the disadvantages of a daily labor requirement for marker administration,

the possible injury to animals during administration and problems in maintaining daily marker intake.

In the second method, output of feces is estimated from the change over time in marker concentration following a single administration of the marker (figure 1). There is a time delay between administration and first appearance in the feces and then the concentration increases to a peak followed by a decrease to below detectable limits.

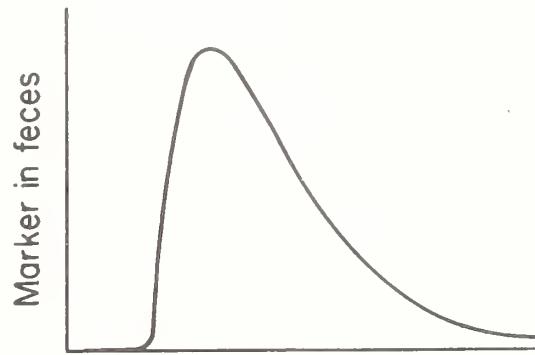


Figure 1. Concentration of marker in the feces after oral administration.

A major disadvantage of this method is the required frequency of fecal collection to obtain the curve in figure 1. Several 1- and 2-compartment models have been developed to describe the marker appearance curve (Pond et al., 1984). In most grazing studies the one compartment model with time delay and gamma two age dependency has given the best fit. The model is:

$$y = (k_0 \times \lambda_1 (t-t_d) \times e^{-(\lambda_1 \times (t-t_d))}) / 0.59635$$

where y = concentration of marker,
 k_0 = concentration of marker if
 instantaneously mixed in the compartment,
 λ_1 = age dependent rate parameter,
 t_d = time delay,
 t = time after marker administration,

Output of feces (FO) is then computed as:

$$FO, \text{ g/d} = \frac{\text{Marker dosed, g/d} \times \lambda_1 \times 24 \times 0.59635}{k_0}$$

In addition to fecal output the mean retention time (MRT) of the marker and fill of undigested dry matter in the digestive tract (fill) can be determined:

$$MRT, h = 2/\lambda_1 + t_d$$

$$\text{fill, g} = \frac{\text{marker administered}}{k_0, \mu\text{g/g}}, \mu\text{g}$$

This additional information cannot be calculated when marker is administered daily. Several indigestible external markers have been utilized and are described below.

Chromic oxide (Cr_2O_3) - The oldest and most commonly used marker is chromic oxide powder. Chromic oxide is water insoluble and is associated with neither the solid (particle) nor liquid components of digesta. This lack of association can result in sedimentation in the rumen and sporadic transfer through the gastrointestinal tract (Ellis et al., 1982). Part of this problem has been reduced with the incorporation of Cr_2O_3 into paper or cellulose. The shredded paper is then administered to the animal. The movement of Cr_2O_3 incorporated on paper is more representative of digesta particles than Cr_2O_3 powder. However, availability of this paper product is low.

Diurnal variation in the excretion of Cr_2O_3 is a normal phenomenon in ruminants and can increase variation in chromium concentration in the feces (Hardison and Reid, 1953). Therefore, samples must be taken that represent several time periods.

Ferric oxide - As with chromic oxide, ferric oxide may accumulate in the rumen and may not remain completely mixed with digesta. Variable and poor recovery has reduced its popularity as a marker in ruminants (Pond et al., 1985).

Silver sulfide (Ag_2S) - The sulfides of several heavy metals have been evaluated as markers. Silver sulfide is insoluble in the digestive tract, recoverable in the feces and analytically determined with great accuracy. However, expense has limited its use as a fecal output marker (Schneider and Flatt, 1975).

Chelated minerals - Chelation products of Chromium, cobalt and several rare earths with ethylenediaminetetraacetic acid (EDTA) or diethylenetrinitrilotriacetate acid (DTPA) have been used as indigestible markers (Ellis et al., 1982). These chelation products are water soluble and presumably follow the flow of solubles through the gastrointestinal tract. Some binding of Cr-EDTA to particles in the rumen has been reported.

Polyethylene glycol (PEG) - This material is extremely water soluble and nearly completely recovered in the feces. Analytical procedures are poor and problems have been noted with feeds high in tannins (PEG precipitates) (Ellis et al., 1982). This has reduced its popularity as a marker of liquids.

Chromium mordanted fiber - To measure the flow of fiber through the gastrointestinal tract requires that the marker remain associated with the fiber. The chromium mordant procedure was developed (Uden et al., 1980) to attach chromium to the forage fiber with it remaining bound throughout the ruminant digestion process. The procedure calls for adding chromium equal to 12-14% of the weight of the fiber. At this high level, the density

of the fiber is increased and passage of the marked fiber may be different than that of the unmarked fiber (Ehle et al., 1984). To minimize this problem, this procedure has been altered in our laboratory so that chromium is added at a rate of 6-8% of the fiber weight. At present, this is the most widely used fiber marker.

Rare Earth labeled fiber - The rare earths including lanthanum, cerium, europium, samarium, neodymium, dysprosium, erbium, terbium and lutetium and the elements hafnium and scandium, have been used to mark fiber. The procedure for labeling the fiber has evolved from sprinkling of a water soluble marker solution on the fiber to soaking the marker solution and washing the fiber to binding the marker at different pHs with EDTA. The rare earths are not as tenaciously bound in the soaking procedure to the fiber as occurs in the mordanting process. This procedure has been criticized because of possible marker transfer to unlabeled fiber and possibly to the liquids (Ellis et al., 1982).

MARKER APPLICATIONS IN GRAZING STUDIES

To predict intake on pasture using markers requires that the quality of the forage consumed by the animal be estimated. This requires additional sampling regardless of the marker or marker procedure used. Simply using forage yield samples or cuttings will not likely account for the selection exhibited by the animal. To obtain a representative sample of the selected forage the use of a rumen or esophageal cannulated animal is recommended. Forage selected by grazing animals can be readily obtained by using an animal fitted with an esophageal cannula. Hand plucked samples are an alternative where surgically modified animals are not available.

Digestibility of forage representing the animal's diet can then be estimated either by an in vitro (Burns and Cope, 1974) analysis or by using an internal marker. Best results from markers have been obtained with INDF or lignin using equation (2).

Estimates of fecal output are more difficult to obtain. If the trial involves supplementation with grain, a marker can be administered to the animal as part of the grain portion. Chelates of erbium, chromium, cobalt and dysprosium have been added in liquid form to the supplement, allowed to dry and individual allowances weighed out to be fed once or twice daily. Animals must be individually fed and all of the marker must be consumed. Fecal output is then estimated from the mean of representative samples using equation (4).

Most grazing studies do not involve grain supplementation and do not utilize individual feeding stalls. Therefore, the marker must be administered daily to the animal by dosing.

Dried marked fiber (sometimes using rice hulls as a carrier) is usually dosed with a balling gun. Liquid marker can be administered orally with a syringe. Ellis (1978) developed a pump to deliver a set amount of marker at prescribed times. The device fits inside the lid of a rumen cannula and has been used successfully.

If the daily administration technique is used and the pasture area is small, care must be exercised to avoid contaminating the pasture with the marker. Such contamination will markedly reduce the measured output of feces. This has happened after using chromic oxide as the daily dose marker on the same pasture for several years.

The technique we have found most workable and reliable is the single marker administration and fecal sampling to obtain the saturation-desaturation curve presented in figure 1. Generally, both a liquid marker (cobalt-EDTA) and a particle marker (chromium mordanted fiber) are dosed. From this curve, the output of feces along with the rate of passage, mean retention time and gastrointestinal tract fill are estimated. Animals are dosed at 600-700 h and sampled at 5, 9, 13, 17, 24, 28, 31, 35, 38, 41, 48, 55, 61, 72, 79, 85, 97 and 109 h postdosing. Two sampling periods (h 17 and 41) occur at 2300 h (after dark). Samples are obtained by following animals until they defecate and spooning the feces into prelabeled plastic bags or by moving animals to a squeeze chute for rectal grab sampling. Night time sampling is facilitated by miners head lamps.

The cobalt and chromium in the feces are extracted with acid (Quiroz, 1984) and assayed by atomic absorption spectrophotometry. Other potential markers to be assayed by atomic absorption (in decreasing sensitivity) are ytterbium, erbium and dysprosium. The use of neutron activation analysis greatly increases analytic sensitivity and the number of potential markers (Pond et al., 1985).

Literature Cited

- Burns, J. C., and Cope, W. A. 1974. Nutritive value of crownvetch forage as influenced by structural constituents and phenolic and tannin compounds. *Agron. J.* 66:195-200.
- Ehle, F. R., Bas, F., Barro, B., Martin, R., and Leone, F. 1984. Particulate rumen turnover rate measurement as influenced by density of passage marker. *J. Dairy Sci.* 67:2910-2913.
- Ellis, G. H., Matrone, G., and Maynard, L. A. 1946. A 72 percent H_2SO_4 method for the determination of lignin and its use in animal nutrition studies. *J. Anim. Sci.* 5:285-297.
- Ellis, W. C. 1978. An improved portable rumen infusion pump for grazing research. *J. Anim. Sci. (Suppl 1)*:47:292.
- Ellis, W. C., Lascano, C. E., Teeter, R., and Owens, F. N. 1982. Solute and particulate flow markers. pp. 37-56. In Protein requirements for cattle: Symposium. MP-109 Oklahoma State University.
- Gallup, W. D., Hobbs, C. S., and Briggs, H. M. 1945. The use of silica as a reference substance in digestion trials with ruminants. *J. Anim. Sci.* 4:68-71.
- Hardison, W. A., and Reid, J. T. 1953. Use of indicators in the measurement of the dry matter intake of grazing animals. *J. Nutr.* 51:35-52.
- Holter, J. A., and Reid, J. J. 1959. Relationship between the concentration of crude protein and apparently digestible protein in forages. *J. Anim. Sci.* 18:1339-1349.
- Lippke, H., Ellis, W. C., and Jacobs, B. F. 1986. Recovery of indigestible fiber from feces of sheep and cattle on forage diets. *J. Dairy Sci.* 69:403-412.
- Pond, K. R., Ellis, W. C., and Matis, J. H. 1984. Development and application of compartmental models for estimating various parameters of digesta flow in animals. Texas A & M University, Department of Animal Science Technical Report 84-2.
- Pond, K. R., Ellis, W. C., James, W. D., and Deswysen, A. G. 1985. Analysis of multiple markers in nutrition research. *J. Dairy Sci.* 68:745-750.
- Quiroz, R. A. 1984. Particle size of forage masticate and its effect on digestion, rate of passage, and intake by goats. MS Thesis. N. C. State University.
- Reid, J. T., Woolfolk, P. G., Richards, C. R., Kaufmann, R. W., Loosli, J. K., Turk, K. L., Miller, J. I., and Blazer, R. E. 1950. A new indicator method for the determination of digestibility and consumption of forages by ruminants. *J. Dairy Sci.* 33:60-71.
- Reid, J. T., Woolfolk, P. G., Hardison, W. A., Martin, C. M., Brundage, A. L., and Kaufmann, R. W. 1952. A procedure for measuring the digestibility of pasture forage under grazing conditions. *J. Nutr.* 46:255-269.
- Schneider, B. H., and Flatt, W. P. 1975. The evaluation of feeds through digestibility experiments. The University of Georgia Press, Athens, Georgia.

Thoney, M. L., Palhof, B. A., DeCarlo, M. R., Ross, D. A., Firth, N. L., Quass, R. L., Perosio, D. J., Duhaime, D. J., Rollins, S. R., and Nour, A. Y. M. 1985. Sources of variation of dry matter digestibility measured by the acid insoluble ash marker. *J. Dairy Sci.* 68:661-668.

Uden, P., Colucci, P. E., and Van Soest, P. J. 1980. Investigation of chromium, cerium and cobalt as markers in digesta rates of passage studies. *J. Sci. Food Agric.* 31:625-631.

BUSINESS MEETINGS AND RELATED MATTERS

Forty-second Southern Pasture and Forage Crop Improvement Conference
Athens, GA 30602
16 April 1986

Minutes of the Business Meeting

Dr. Wilfred McMurphy, Chairman, called the meeting to order at 4:30 p.m. Because SPFCIC met jointly with the American Forage and Grassland Council, the usual format was not followed. The business meeting began with a roll-call of states.

A financial report was made by R. S. Kalmbacher indicating that \$2664.63 was in the account in Wauchula, Florida. Motion was made by Harlan White, seconded by Paul Mueller to accept the treasurer's report. Passed.

A motion was made by Joe Burns to accept the minutes of the 41st meeting as published in the 41st Proceedings. Seconded by Don Ball. Passed.

A report was made by nominations committee (composed of Harold Brown (Georgia) chairman, Harlan White (Virginia), and R. S. Kalmbacher (Florida)). They placed the name of Warner Essig (Mississippi) for chairman, elect-elect. There were no nominations from the floor. Joe Burns moved nominations be closed, seconded by Lee Mason. Warner Essig was elected by acclamation. Jim Green was nominated for secretary-treasurer (three year term 1987-1989). There were no nominations from the floor. Billy Nelson moved that nominations be closed; seconded by Charles Ruelke. Jim Green was elected by acclamation.

A report was made by Billy Nelson (chairman) of the resolutions committee. Lee Mason and Joe D. Burns also composed this committee. A copy of the Resolution No. 1 is attached. A motion was made by Wade Faw to accept Resolution No. 1 recognizing the staff and administration of the University of Georgia, seconded by Joe D. Burns. Passed. A second resolution (attached) recognizing the contributions of John Miller, Coastal Plain Experiment Station. A motion to accept the Resolution No. 2 was made by Roy Blazer, seconded by Don Ball. Passed.

A letter from Glenn B. Collins, Associate Dean for Research for the University of Kentucky, invited the 44th SPFCIC to meet in Kentucky in 1988. A motion to accept the invitation was made by J. Paul Mueller, seconded by K. Quesenberry. Passed.

The gavel was passed from Wilfred McMurphy to Hagen Lipke. With no further business, the meeting was adjourned.

Resolution 1.

WHEREAS, membership of the 42nd Southern Pasture & Forage Crop Improvement Conference has gleaned much information and great benefits from participation in the Conference, and

WHEREAS, such information and benefits could not have been realized without the friendly hospitable efforts of the staff and administration of The University of Georgia and USDA, ARS.

BE IT RESOLVED that the 42nd Conference express grateful appreciation to the staff, faculty, and administration of The University of Georgia for their gracious hospitality, imaginative programming, well-planned and effective tour of the forage-animal research facilities, and review of selected research programs.

That special recognition be extended to Dr. William Flatt, Dean, College of Agriculture, Dr. Clive Donoho, Director, Georgia Agriculture Experiment Station, Dr. William Colville, Head, Department of Agronomy, Dr. David Spruill, Head, Department of Animal Science, and Dr. Maurice Frere, Director, USDA Southern Piedmont Research Center, Watkinsville.

That signal recognition be extended to Dr. Carl Hoveland and all members of the local arrangements committee,

to Conference Chairman, Wilfred McMurphy; Immediate Past-Chairman, Billy Nelson; and Secretary, Robert Kalmbacher (Secretary since 1980),

to Session Chairmen, David St. Louis, Utilization; Wade Faw, Extension; Gary A. Pederson, Breeding; Geoff Brink, Ecology-Physiology,

to all who presented conference papers, and

to financial contributors toward conference expenses.

Resolution 2.

WHEREAS, membership of the Southern Pasture & Forage Crops Improvement Conference has greatly benefited over the years, since 1981, from the contributions of John Miller, Research Agronomist, Coastal Plain Experiment Station, Tifton, Georgia, contributions which have included assembling program papers and related records into the Annual Proceedings of the conference.

BE IT THEREFORE RESOLVED that the 42nd Conference express grateful appreciation to Dr. Miller for his unselfish and effective service.

CONFERENCE REGISTRANTS

- ✓ AKIN, D. E., Russell Research Center, P. O. Box 5677, Athens, GA 30613
- ALBRECHT, K. A., Agronomy Dept., 305 Newell Hall, University of Florida, Gainesville, FL 32611
- ✓ ALLEN, V. G., Dept. of Agronomy, VPI & SU, Blacksburg, VA 24061
- BAGLEY, C. P., West La. Exp. Sta., P. O. Box 26, Rosepine, LA 70659
- BALL, D. M., Extension Hall, Auburn University, AL 36849
- BALLERSTADT, P. J., Graduate Student, 740 Sims Road, Georgetown, KY 40324
- BALTENSPERGER, D., Agronomy Dept., University of Florida, Gainesville, FL 32611
- BARNES, R. F., P. O. Box 19227, New Orleans, LA 70179
- BELESKY, D. P., P. O. Box 555, Watkinsville, GA 30677
- BLASER, R. E., Dept. of Agronomy, Virginia Polytechnic Institute, Blacksburg, VA 24061
- BOUTON, J. H., 3111 Plant Sci. Bldg., University of Georgia, Athens, GA 30602
- BROWN, R. H., Dept. of Agronomy, University of Georgia, Athens, GA 30602
- BURNS, J., P. O. Box 1071, University of Tennessee, Knoxville, TN 37901-1071
- BURNS, J. C., Dept. of Crop Science, Box 7620, N. C. State University, Raleigh, NC 27695-7620
- BURRIS, R., Research & Education Center, University of Kentucky, P. O. Box 469, Princeton, KY 42445
- ✓ BURTON, G. W., Forage & Turf Rsch. Ctr., Georgia Coastal Plain Expt. Sta., Tifton, GA 31793-0748
- CARR, S. B., 276 Animal Sci. Bldg., VPI, Blacksburg, VA 24061
- CHAMBLISS, C., Agronomy Dept., University of Florida, Gainesville, FL 32611
- ✓ COLEMAN, S. W., USDA, ARS, Route 3, El Reno, OK 73036
- COLLINS, M., Agronomy Dept., University of Kentucky, Lexington, KY 40546
- ✓ CONGER, B. V., Dept. of Plant & Soil Sci., Box 1071, University of Tennessee, Knoxville, TN 37901-1071
- ✓ ELY, L. D., Dept. of Dairy Sci., University of Georgia, Athens, GA 30602
- ESSIG, H. W., Animal Science Dept., Mississippi State University, Mississippi State, MS 39762
- EVANS, J. K., Dept. of Agronomy, N-222K Ag. Science Bldg.-N, University of Kentucky, Lexington, KY 40546
- EVERS, G. W., P. O. Box 728, TAMU Agri. Res. Station, Angleton, TX 77515
- FAW, W. F., 255 Knapp Hall, Louisiana State University, Baton Rouge, LA 70803
- ✓ FONTENOT, J. P., Dept. of Animal Sci., VPI & SU, Blacksburg, VA 24061
- FRERE, M.H., USDA-ARS, P. O. Box 555, Watkinsville, GA 30677
- GERKEN, J., Animal Science Dept., VPI & SU, Blacksburg, VA 24061
- GOODROAD, L. L., Dept. of Agronomy, University of Georgia, Griffin, GA 30212
- GREEN, J. T., Dept. of Crop Science, Box 7620, N. C. State University, Raleigh, NC 27695-7620
- HAALAND, R., Sun Rise Seed Co., P. O. Box 2085, Auburn, AL 36830
- HANKINS, B. J., P. O. Box 391, Little Rock, AR 72203
- HILL, G. M., Dept. of Animal Sciences, Coastal Plain Experiment Station, Tifton, GA 31793-0748
- HILL, N. S., Agronomy Dept., University of Georgia, Athens, GA 30602
- HOVELAND, C. S., Dept. of Agronomy, University of Georgia, Athens, GA 30604
- IVY, R. L., P. O. Box 124, Prairie Experiment Station, P. O. Box 124, Prarie, MS 39739
- JOOST, R., Southeast Research Station, P. O. Drawer 567, Franklinton, LA 70438
- KALMBACHER, R. S., AREC, Rt. 1, Box 62, University of Florida - Agronomy, Ona, FL, 33865
- KAISER, C. J., Rt. 1, Box 132, Simpson, IL 62985
- KIMBROUGH, E. L., Agronomy Dept., Mississippi State University, Mississippi State, MS 39762
- KINCHELOE, S., International Minerals and Chemicals, Agronomic Services, 421 E. Hawley Street, Mundelein, IL 60060

- KINC, C. C., Jr., Dept. of Agron. & Soils,
Funchess Hall, Auburn University, AL
36849
- KNIGHT, W. E., Crop Sci. Res. Lab, P. O. Box
272, Mississippi State, MS 39762
- LACEFIELD, C. D., Research and Education Center,
University of Kentucky, P. O. Box 469,
Princeton, KY 42445
- LIPPKE, H., P. O. Box 728, TAMU Agri. Res.
Station, Angleton, TX 77515
- MASON, L. F., S. E. La. Dairy & Pasture Exp.
Sta., P. O. Drawer 567, Franklinton, LA
70438
- MATCHES, A. C., P. O. Box 4169, Texas Tech
University, Lubbock, TX 79401
- MCCORMICK, M. E., LSU Southeast Res. Sta.,
Franklinton, LA 70438
- MCCLAIN, E. F., Dept. of Agron. & Soils,
Clemson University, Clemson, SC 29631
- MCMURPHY, W. E., Dept. of Agronomy, Oklahoma
State Univ., Stillwater, OK 74078
- MILLER, J. D., Agronomy Dept., Coastal Plain
Experiment Station, P. O. Box 748,
Tifton, GA 31793-0748
- MISLEVY, P., AREC, Rt. 1, Box 62, University
of Florida - Agronomy, Ona, FL 33865
- MONSON, W. C., USDA Forage & Turf Rsch. Ctr.,
Georgia Coastal Plain Station, Tifton,
GA 31793
- MOORE, J. E., Dept. of Animal Science,
University of Florida, Cainesville,
FL 32611
- MOOSO, C., Rosepine Res. Sta., P. O. Box 26,
Rosepine, LA 70659
- MOSIJIDIS, J., Dept. of Agronomy & Soils,
Auburn University, Auburn University,
AL 36830
- MOUTRAY, J. B., Jr., Agri-Pro, RFD 3, Ames,
IA 50010
- MUELLER, J. P., Dept. of Crop Science, Box 7620,
N.C. State University, Raleigh, NC
27695-7620
- NELSON, B. D., Southeast La. Exp. Sta., 530
Cleveland Street, Franklinton, LA 70438
- OCUMPAUCH, W. R., Star Rt. 2, Box 43C, TAMU
Agri. Res. Station, Beeville, TX 78102
- PEDERSON, C. A., P. O. Box 5248, Mississippi
State, MS 39762
- PEDERSON, J., Agronomy & Soils Dept., Funchess
Hall, Auburn University, AL 36849
- PINKERTON, B., TAMU Agri. Res. & Ext. Ctr.,
2415 E. WHy 83, Weslaco, TX 78596
- POND, K. R., Dept. of Animal Science, Box 7621,
N. C. State University, Raleigh, NC
27695-7621
- POWELL, J. B., Russell Research Center, 170
Creekshore Drive, Athens, CA 30606
- PRATT, J. N., Soil & Crop Sci., Texas A&M
University, College Station, TX 77843
- PRINE, G. M., Dept. of Agronomy, University of
Florida, Cainesville, FL 32611
- QUESENBERRY, K. H., Dept. of Agronomy, Univer-
sity of Florida, Cainesville, FL 32611
- RASNAKE, M., Research & Education Center,
University of Kentucky, P. O. Box 469,
Princeton, KY 42445
- REEVES, S. A., Jr., Box 220, Overton, TX 75684
- REYNOLDS, J. H., Dept. of Plant & Soil Sci.,
P. O. Box 1071, University of Tennessee,
Knoxville, TN 37901-1071
- RICE, H., Agronomy Specialist, Robinson
Substation, Quicksand, KY 41363
- RICE, J. S., 277 P & AS Bldg., Clemson Univer-
sity, Clemson, SC 29631
- ROBINSON, D. L., Agronomy Dept., Louisiana State
University, 211 Parker Agriculture Center,
Baton Rouge, LA 70803
- ROUQUETTE, F. M., Drawer E, TAMU Agri. Res. &
Ext. Center, Overton, TX 75684
- RUELKE, O. C., Dept. of Agronomy, 2195 McCarty,
University of Florida, Cainesville, FL
32611
- ST. LOUIS, D., P. O. Box 193, Poplarville, MS
39470
- SCHANK, S. C., 2183 McCarty Hall, University
of Florida, Cainesville, FL 32603
- SCHMIDT, S. P., Animal & Dairy Sci., Auburn
University, Auburn, AL 36849
- SCHROEDER, J., Coastal Plain Experiment Station,
Agronomy Dept., P. O. Box 748, Tifton, GA
31793-0748
- SMITH, A. E., Georgia Expt. Station, Dept. of
Agronomy, Griffin, GA 30212
- STANDAERT, J. E., Dept. of Economics, Box 8109,
N. C. State University, Raleigh, NC
27695-8109

STEPHENSON, R., Rt. 1, Box 62, Ona, FL 33865.

STRINGER, W. C., Dept. of Agron. & Soils,
Clemson University, Clemson, SC 29631

STUEDEMANN, J. A., Southern Piedmont Conserva-
tion, USDA, ARS, SWCRD, P. O. Box 555,
Watkinsville, GA 30677

TAYLOR, N. L., Agronomy Dept., N-222F Ag.
Science Bldg.-N, University of Kentucky,
Lexington, KY 40546

TAYLOR, T. H., 1253 Kastle Rd., Lexington, KY
40503

TEMPLETON, W. C., 800 Brookhill Drive,
Lexington, KY 40502

THOMPSON, W. C., North American Plant Breeders,
121 Dantzler Court, Lexington, KY 40503

THRO, A. M., Dept. of Agronomy, Louisiana
State University, Baton Rouge, LA 70803

TOLLNER, E. W., Agric. Eng. Dept., Griffin,
GA 30212

TOPEL, D. G., Dept. Animal & Dairy Science,
Auburn University, Auburn, AL 36849

UNDERSANDER, D., 6500 Amarillo Blvd., TAMU
Ag. Res. & Ext. Center, Amarillo, TX
79106

WACEK, T., Kalo Agric. Chemicals, Inc.,
P. O. Box 12567, Columbus, OH 43212

✓ WELLS, H. D., Dept. of Plant Pathology,
Georgia Coastal Plain Exp. Sta., P. O.
Box 748, Tifton, GA 31793-0748

WHITE, H. E., Coop. Ext. Service, Virginia
Polytechnic Inst., Blacksburg, VA 24061

WILKINSON, S., USDA-ARS, Sou. Piedmont Conser-
vation Res., P. O. Box 555, Watkinsville,
GA 30677

✓ WINDHAM, W. R., R. B. Russell Research Ctr.,
P. O. Box 5677, Athens, GA 30604

WITHERS, F. T., Jr., Animal Research Center,
P. O. Box ES, Mississippi State, MS
39762

WOLF, D. D., Dept. of Agronomy, Virginia
Polytechnic Inst., Blacksburg, VA
24061

WOODWARD, W. T. W., Dept. of Alfalfa Breeding,
P. O. Box 85, Johnston, IA 50010

